WADC TECHNICAL REPORT 54-151

A MACHINE SYSTEM FOR ACCEPTING, STORING, AND SEARCHING ENGINEERING DATA ON ELECTRONIC COMPONENTS

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WRIGHT AIR DEVELOPMENT CENTER

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Wright Air Development Center
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Wright-Patterson Air Force Base, Ohio

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FOREWORD

This final report prepared by Battelle Memorial Institute, Columbus, Ohio, covers accomplishments and research on Air Force Contract AF 33(038)-1229 under RDO No. 112-140 titled, "Evaluating and Rerating of Electronic Components." Work at Battelle Memorial Institute was started on December 28, 1948, and this report covers the work through March 30, 1954. The project was administered under the direction of Mr. D. C. Bedwell and Mr. V. S. Kozloff, for the Electronic Components Laboratory, Directorate of Research, Wright Air Development Center.

The following members of Battelle Memorial Institute contributed to the research: H. J. Behm, R. A. Corby, R. L. Davis, L. R. Jackson, A. T. Maierson, R. C. McMaster, H. E. Patteo, and H. B. Thompson. Staff members who supervised the work directly as project engineers were: R. L. Davis, A. T. Maierson, R. E. Martin, D. B. J. Bridges, and H. J. Behm. R. L. Merrill and A. P. Jerencsik acted as Assistant Supervisors and R. C. McMaster as Supervisor.

ABSTRACT

This report is a summary of the research work which has produced the design of a system to collect, store in condensed form, search rapidly by machine, and disseminate comprehensive engineering data on electronic components.

The report describes the elements of a machine-sorted punched-card system for recording, searching, and tabulating data on any electronic component. It presents detailed data sheets, definitions, codes, and instructions for processing input data on a typical component group (capacitors). Fifteen special reports present similar detailed ECIC designs for fifteen component groups. A résumé is presented of the work done toward the development of life-rating test methods and of that on automatic component-testing equipment.

Also presented are discussions and studies on (1) the data-collecting problem, (2) suggested organization and personnel requirements, and (3) cost estimates for building up and operating an ECIC. Three general plans for implementing the system are discussed.

PUBLICATION REVIEW

FOR THE COMMANDER:

R. E. Long
for RICHARD S. CARTER
Colonel, USAF
Chief, Electronic Components Laboratory
Directorate of Research

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INTRODUCTION

Five years of research and development, representing forty man-years of effort, have resulted in a system believed to be capable, upon implementation, of appreciably reducing the engineering time and the cost of selecting proper components for electronic equipment.

The ELECTRONIC COMPONENT INFORMATION CENTER (ECIC) is the name given to the type of organization that has been designed and could be implemented to operate such a system.

The pictures on the following page illustrate briefly the "what", "why", and "how" of the system. They show how an ECIC might function to provide valuable service to electronic equipment designers. They should not be construed as picturing an information center already in operation. In this hypothetical case, an electronic-equipment designer in an aircraft-manufacturing plant is shown reporting progress on a new design to his chief engineer. His design is at a stage where the designer must know whether the parts he needs are available, and, if so, who makes them. Also, if certain requirements of some items cannot be met by existing components, the designer wants to know what products of those available come closest to meeting these requirements. The job of answering these questions is turned over to the ECIC (which is in hypothetical full-scale operation). By searching all the applicable data for each component, as punched on IBM cards, the ECIC supplies the answers in a short time, releasing the designer, meanwhile, to other productive effort. This the ECIC does by:

(1) Analyzing the inquiry and establishing the search routine.

(2) Selecting the appropriate card file.

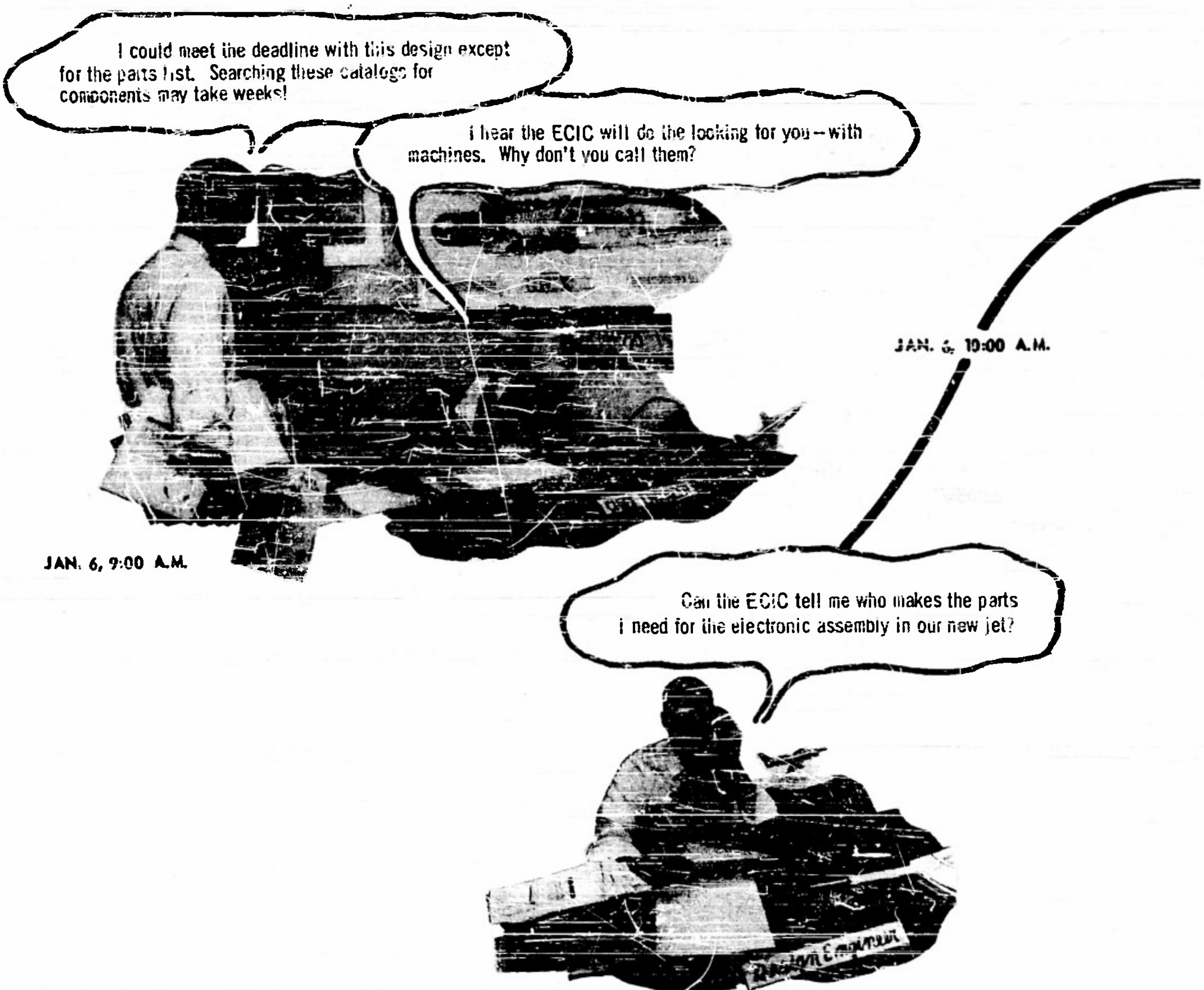
(3) Searching each selected card deck, with either an electronic statistical machine or a collator, at a minimum rate of 450 cards per minute. This operation automatically separates the desired cards from the others.

(4) Tabulating the data from the separated cards automatically on a Cardatype machine or on a standard tabulator.

(5) Verifying the correctness of the tabulated answers.

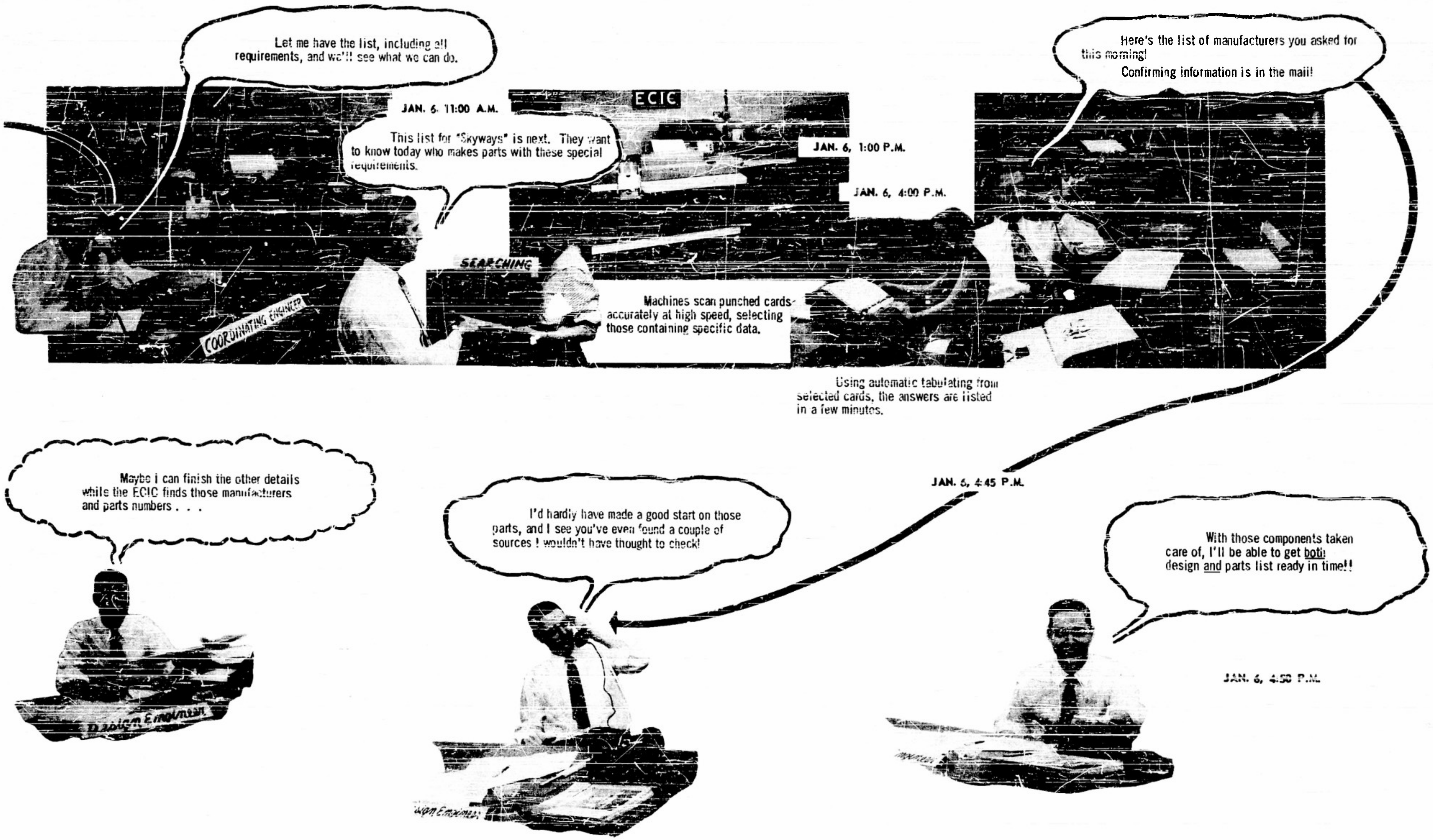
(6) Communicating the answers to the inquirer.

The details of the system as designed, and of the related research work, are presented in this report. Parts of the work that were described in earlier reports are covered here only by reference.



ECIC
SERVICE TO DESIGN ENGINEERS

FIGURE 1.



Let me have the list, including all requirements, and we'll see what we can do.
JAN. 6, 11:00 A.M.
This list for "Skyways" is next. They want to know today who makes parts with these special requirements.
ECIC
COORDINATING ENGINEER
SEARCHING
Machines scan punched cards accurately at high speed, selecting those containing specific data.
JAN. 6, 1:00 P.M.
JAN. 6, 4:00 P.M.
Using automatic tabulating from selected cards, the answers are listed in a few minutes.
Here's the list of manufacturers you asked for this morning!
Confirming information is in the mail!
Maybe I can finish the other details while the ECIC finds those manufacturers and parts numbers . . .
I'd hardly have made a good start on those parts, and I see you've even found a couple of sources I wouldn't have thought to check!
JAN. 6, 4:45 P.M.
With those components taken care of, I'll be able to get both design and parts list ready in time!!
JAN. 6, 4:50 P.M.

The Problem of Selecting Reliable Electronic Components

Electronics in Modern Weapons and Machines

The electronic-equipment industry in the United States is a vital part of our industrial and military strength. Modern design, both of weapons and machines, has made electronics indispensable. This is evident from the amount of money spent for electronic equipment. In 1952, the total investment in such equipment was six billion dollars, two-thirds of which bought military equipment.* The growth of the electronics industry has been phenomenally rapid, and the indications are that its expansion will continue.

Modern military aircraft, for instance, would be practically inoperable without electronic equipment. The heavy bomber uses over 2000 electron tubes and many more thousands of other electronic components. Its electronic equipment represents a large portion of the total production cost of the plane — in both man-hours and money. Other major weapons and industrial machines are approaching a similar degree of dependence upon electronic equipment for their production and performance.

Importance of Efficient Component Selection

The time and money required for the development of improved models of modern machines and weapons are affected greatly by the expense and time involved in developing their vital electronic systems. These systems, for instrumentation, communication, guidance, and control, largely determine the equipment's over-all design and performance limitations. The proper selection of the most reliable and effective components is a critical step — often the most costly and difficult step — in the development of these electronic systems.

At present, the design engineer searches his experience and the catalogues he has at hand — laboriously and tediously — for the components his design requires. For parts demanding special requirements, he may spend weeks in the search. For many of the data, he probably will have to write to manufacturers, because the catalogue information is inadequate. On some components, still more information is needed, so the engineer must request that a special test program be set up to determine the unknown performance characteristics. This search for information, much of which already exists, consumes an important part of a design engineer's time.

*Tele-Tech, page 47 (January, 1953).

Under conditions of scarce technical manpower, this inefficient use of an engineer's time is a serious problem. Under the pressure of impending deadlines, the designer may be forced to specify electronic components whose performance he can only guess. When proper components cannot be selected promptly, entire development programs may be delayed or may require costly reworking. This greatly increases the expense, and delays the delivery of satisfactory models.

A Major Cause of Electronic-Equipment Failures

When equipment having poorly selected components appears in full-scale production, its effective functioning is often prevented by premature component failures. Sometimes these component failures cause complete operational failure of large equipments. This results in the loss of large investments in terms of both time and money — sometimes of lives, as well. The problem is particularly important when electronic components are required to operate under heavy loading in severe, abnormal ambient conditions.

Recently, a comprehensive study was made of the case histories of some 1100 electronic components that had failed in service in Army, Navy, or Air Force equipment.* Basic causes of failure were analyzed and reported statistically. Ninety-three per cent of the failures were classed as premature — that is, they occurred before the expected end of the service life of the component. Forty-three per cent were attributed to faulty or inadequate engineering.

Mr. R. M. C. Greenidge of the Bell Telephone Laboratories, author of a recent paper entitled, "The Case of Reliability Versus Defective Components et al.", in discussing the above-mentioned study, says:

> "The lesson from all of this is not new: More detailed knowledge of all the conditions to which components and equipments will be subjected is needed to permit reliable designing. We need to know the true capabilities of the components we have so that they are not misapplied, and, where necessary, we need to provide more suitable components. We need to conduct field trials to prove in engineering judgments, or to correct mistakes before quantity production begins. We need to write better specifications and enforce them in order to get reliable performance. If equipments so designed, pre-tried and manufactured, are properly installed and operated, the reliability problem will be essentially solved."

*See paper entitled "The Program on Reliability of Electronic Equipment", by Lewis M. Clement, Chairman, Advisory Group on Reliability of Electronic Equipment, Committee on Electronics, Office of the Secretary of Defense (October, 1953). This paper contains a résumé of a Bell Telephone Laboratory study sponsored by the United States Navy, Bureau of Ships.

Waste Through Duplicate Testing

The total cost to the nation of the present difficult and time-consuming methods of selecting electronic components is immense, and much of this expense is unnecessary. Designers today are largely dependent on manufacturer's data and the results of specification tests for component information. Neither of these sources normally includes data on performance under abnormal loading or environmental conditions. Consequently, the individual manufacturer of electronic equipment is often forced to test many components over wide ranges of operating conditions to determine their suitability. Other firms then repeat the same test procedures on similar components because no practical means exists for transmitting such data from one user to another. It is estimated that 10 man-hours are required to test the average single component, and scores of identical components may have to be tested to provide valid data for each test condition. The cost of such tests, often unnecessarily duplicated, may be a significant portion of the total equipment-development cost. For military preparedness, the time involved is of even greater importance than the expense.

The ECIC Solution

The Research Program

To provide a practical means of speeding up and improving the quality of electronic-component selection in equipment design, the United States Air Force has sponsored a research project to develop a mechanized system for storing and searching engineering data. The resulting system is the product of a five-year research program at Battelle Memorial Institute, sponsored by the Electronic Components Laboratory of the Wright Air Development Center in the Air Research and Development Command.

The ECIC System — Technical Design

General. The ECIC system has been designed to handle electronic-component data efficiently from source to user. Its over-all program entails the gathering, evaluating, storing, searching, and disseminating of available technical information on the engineering characteristics of electronic components for use under both normal and special operating conditions. The significance of each item of component data has been defined. Appropriate methods of testing, compatible with military specifications and accepted industrial practice, have been designated and described. Efficient

procedures have been developed for reporting test results and manufacturers' data. The essence of these procedures is contained in the detailed work sheets that have been designed to facilitate the introduction of data into the ECIC system.*

Methods of coding and organizing component data have been developed to condense information for storage on punched cards in minimum space. Practical machine-searching techniques have been proven capable of (1) rapidly selecting the desired information from these cards and (2) reproducing it for transmittal to the inquirer on a "same day" basis. These data may be tabulated, or transmitted by teletypewriter directly from machine operations. This eliminates manual transcription, with its attendant high cost and chance of error.

The system details for the following fifteen component groups have been completed:

Resistors	Crystals	Dry-Disk Rectifiers
Relays	Vibrators	Indicating Instruments
Motors	Inductors	Fuses
Dynamotors	Batteries	Plugs, Sockets, and Connectors
Capacitors	Switches	Lamps

The data sheets (basic tool for organizing input data for direct transfer to punched cards), together with complete codes, definitions, test methods, and instructions, have been presented in detail in fifteen special ECIC reports, one for each of the components listed above. Detailed work sheets on capacitors are shown, for example, starting on page 46.

Upon insertion of available data, requiring many additional man-years of effort, the ECIC could be operated to provide service covering the 15 component groups listed above. The same sort of service could be extended to include electron tubes, transformers, and the other components of electronic systems by application of the same ECIC data-handling techniques as were used on the designs for the first 15 components. Preliminary data sheets have been completed on 14 of these additional components. These were presented in a special letter report dated November 18, 1952.

Basic Services. The ECIC system is specifically designed to meet the needs of three important types of users of electronic-component information.

*See the fifteen special ECIC reports for detailed work sheets on components.

(1) The questions of designers, engineers, and technicians concerning technical information would be answered from the Application-Data Card Files. These cards would provide detailed data needed in the selection of components for specific applications. The answers could list, for the engineer, all the known sources for each component.

(2) For research and development planning, the need of administrators and research directors may be for summary information on the state of the art, for entire groups of components. Such answers could be found in the Summary-Data Card Files. These files would contain consolidated technical data on component groups (produced by a single manufacturer and having identical designs, except for primary ratings).

(3) Finally, military procurement agencies and industrial purchasing agents need specific procurement information for ordering new and replacement parts. Such data would be supplied from the Procurement-Data Card Files. The latter contain manufacturers' names, catalogue numbers, type and part numbers, military class and stock numbers, and approximate cost figures.

The three types of card file mentioned above may be used either separately or in conjunction with each other to answer each question most effectively.

Over-All Advantages. Operation of the ECIC would offer distinct advantages to designers and production engineers, to the military services, and to other users of electronic equipment. In brief, the system is capable of providing:

(1) A single center to which all available data on electronic components could be sent -- hence, a single source from which specific answers provided by these data could be obtained.

(2) An efficient, accurate, and economical means of selecting proper electronic components for both normal and special applications

(3) A means of eliminating the need for much of the unnecessary duplicate testing of similar components

(4) A systematized, positive method for keeping component data up to date.

Nontechnical Considerations

Sources of Data. It is important to recognize that the Electronic Component Information Center, which this report describes, is a system for handling data. It will not, in itself, create data. Nor would the ECIC provide application engineering. What it could provide is a tireless, accurate, large-capacity storage for engineering data — design data, performance data, and procurement data. It could recall, by machine system, at high speed, any item or group of items in that storage.

The input information must be obtained from manufacturers' catalogues and test records, from laboratory and field tests, from Qualified Product Acceptance Test Reports, and from operating experience. The system could operate with full effectiveness only with the interest, cooperation, and participation of those who make electronic components, those who test them, and those who use them. The problems foreseen with respect to data collection are discussed more fully in Part II of this report.

Costs of Operating the ECIC. The probable costs of providing effective service through full-scale operation of ECIC have been analyzed and are presented in detail in Part IV of this report. The results of this study indicate the internal ECIC operational cost, per question answered, to be less than the probable cost of the communication between the Center and the inquirer. It would be considerably below the present cost of obtaining less complete information. (The cost per question answered, as discussed in this report, does not include amortization of the investment in collecting and inserting the original data nor the cost of any testing program to produce new data. Amortization on a ten-year basis would add an estimated 15 per cent to the annual cost figures presented in the last column of Table 4, page 133, for the first ten years.)

Implementation of ECIC. The ECIC is still "in the blueprint stage", with some of the "parts list" incomplete. The essentials of the design have progressed about as far as possible without "pilot plant" operation to eliminate the "bugs". Laboratory-scale model operation has uncovered no major technical difficulties.

Some nontechnical problems that are recognized as being significant to ECIC operation are:

(1) How to effect complete data collection in the most efficient manner

(2) How best to ensure the use of valid data only

(3) How to enlist full technical support of an ECIC operational program by those who make electronic components, those who test them, and those who use them

(4) The possibility of legal complications, especially in the use of unpublished test data

(5) Economic considerations.

Items 1 and 5 have been explored only in a cursory manner, and items 2, 3, and 4 not at all, because they were not part of the research program's objectives.

As the situation appears now, the immediate problem to be solved before implementation can be started is that of obtaining sufficient financial backing (1) to collect and insert fairly complete data on at least one component group, and (2) to initiate question-answering service at "pilot plant" level. This limited operation, for perhaps a one-year period, should:

(1) Prove the capabilities of the system design

(2) Indicate changes necessary to eliminate the inevitable "bugs"

(3) Define clearly the nontechnical problems to be solved

(4) Provide information leading to accurate cost estimates and to effective organizational planning, for full-scale operation

(5) Determine the significance of the five nontechnical problems listed above.

Arrangement of This Report

This final report, covering the entire research project, is arranged:

(1) To introduce the reader to the capabilities of an Electronic Component Information Center as now designed

(2) To describe briefly the various parts of the ECIC system and to summarize the work done on the research program (see Part I, Description of the System, and Part III, Test-Methods Development)

(3) To provide a detailed account of work not previously reported (see Part I, Classification and Coding, and Part IV, Estimated Costs of Building Up and Operating an ECIC)

(4) To discuss a major problem yet unexplored (see Part II, The Problem of Data Collection)

(5) To draw pertinent conclusions from the work done (see Part V).

The description of the ECIC system, as the result of the research work done through June 1952, was covered in Phase Report No. 1, "A Machine System for Accepting, Storing, and Searching Engineering Data on Electronic Components", which was prepared by the Battelle Memorial Institute for the Wright Air Development Center, June 28, 1952. In the pages that follow, the above-mentioned report is referred to as Phase Report No. 1.

For reference purposes, Appendix B presents a list of the reports previously issued and a list of Battelle Memorial laboratory books in which the original accounts of the work are recorded. Names of personnel of the Sponsor's organization and those of Battelle who contributed to the project are listed in Appendix A.

PART I

DESCRIPTION OF THE SYSTEM

Summary

An electronic-component information system has been designed to be capable of furnishing practical service to engineers in selecting the proper components for electronic equipment.

Figure 2 presents a picture sequence as an aid to quick understanding of (1) the type of service the system is designed to provide, and (2) the essential steps by which the heart of the system (data searching) would operate.

This section of the report outlines the major functions of the proposed system and presents detailed descriptions of those phases of the system not previously reported. The principal activities that, together, would constitute the operation of such a system are as follows:

A. <u>Collecting and Processing Input Data</u>

(1) Collecting data (page 26)

(2) Screening and verifying data (page 27)

(3) Coding and converting data to ECIC forms (page 27)

(4) Punching of data on IBM cards (page 27)

(5) Verifying of punching (page 28)

(6) Filing of cards (page 29)

(7) Keeping information up to date (page 29)

B. <u>Answering Questions</u>

(1) Screening of questions (page 93)

(2) Machine searching of card files (page 93)

(3) Machine tabulating and tape-punching of selected data (page 93)

(4) Verifying the accuracy of answers (page 93)

(5) Transmitting replies (page 93)

The rest of this section contains more detailed descriptions of these functions.

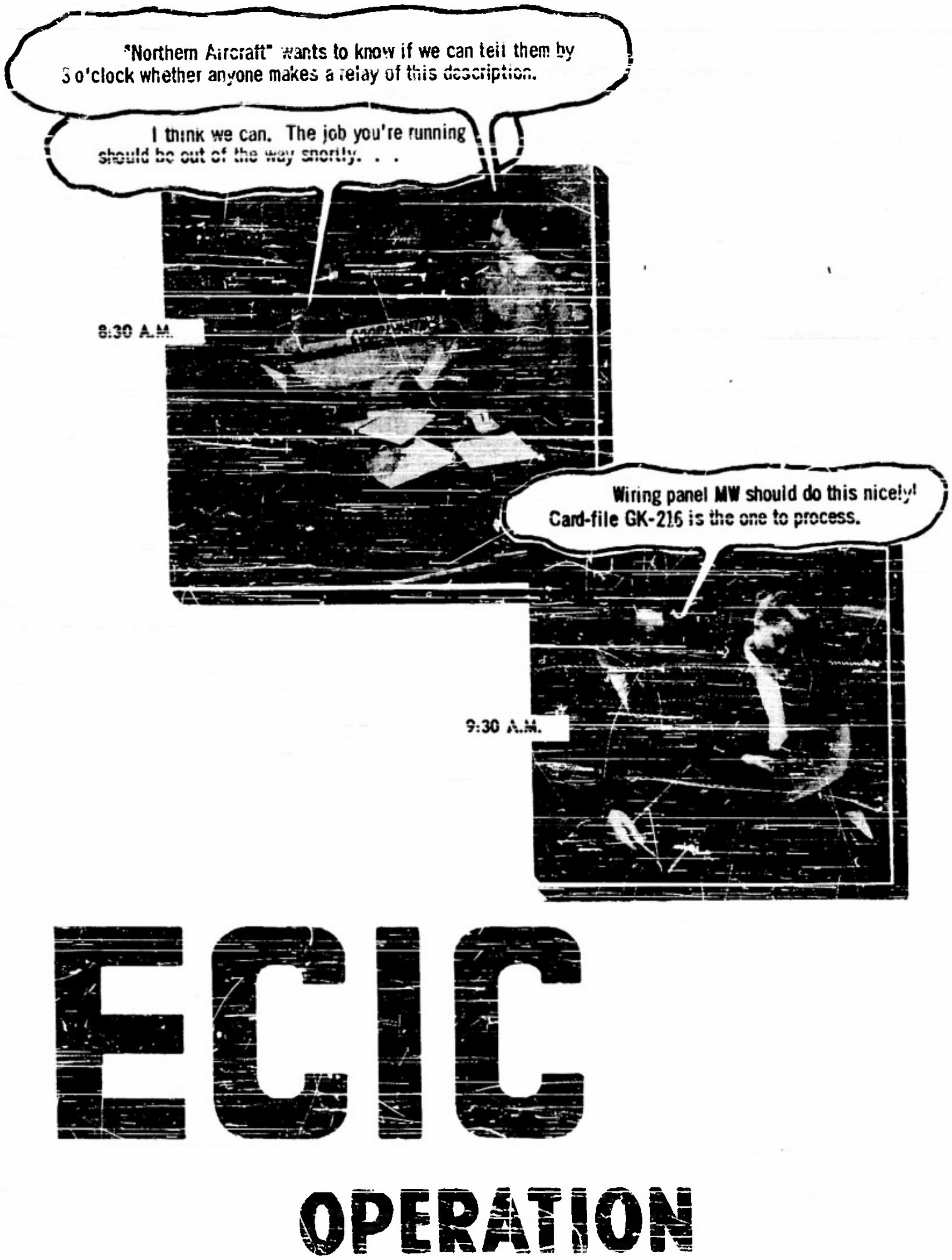
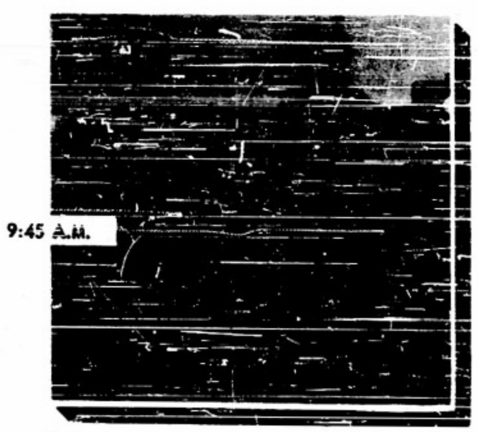
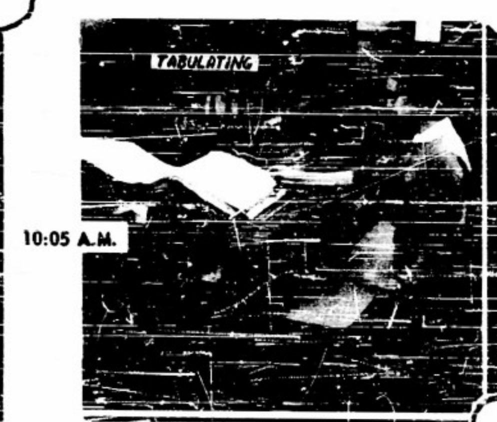

"Northern Aircraft" wants to know if we can tell them by 5 o'clock whether anyone makes a relay of this description.
I think we can. The job you're running should be out of the way shortly. . .
8:30 A.M.
Wiring panel MW should do this nicely! Card-file GK-216 is the one to process.
9:30 A.M.
ECIC
OPERATION

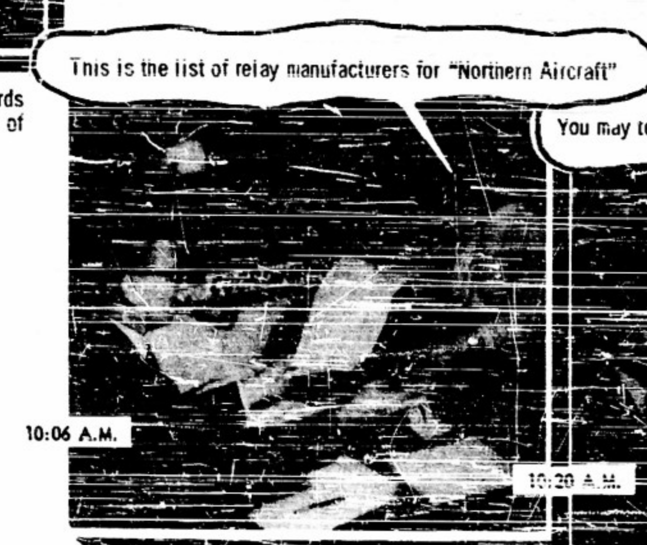
FIGURE 2

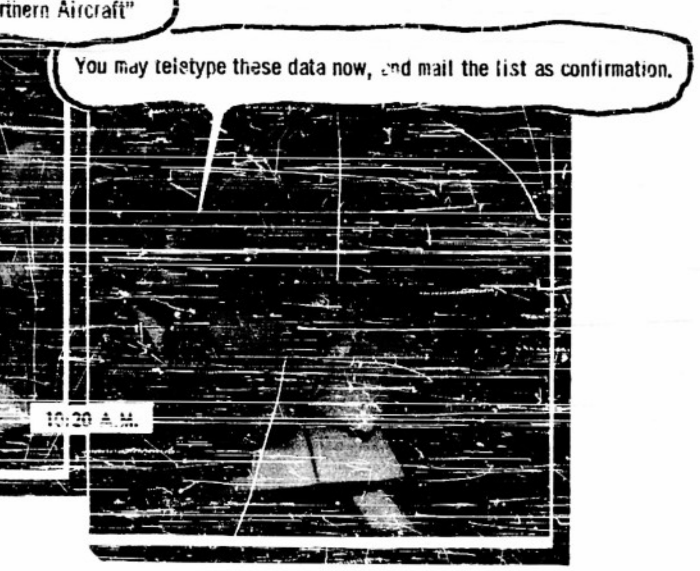


● Extra wiring panel speeds up preparation of the machine for the search – leaves maximum time for searching.



● Automatic tabulating from cards allows operator to handle a group of machines simultaneously.





Forms of Electronic-Component Data

Engineering data on electronic components may be received by the ECIC system in many forms. The system has been so designed that all of these forms of data could be entered readily in the punched-card files. In some cases, simple codes or special devices would be used to condense (but not abbreviate) data for transfer to punched cards. Many data can be punched directly into cards without transformation.

Electronic-component data may be divided into two general classes: (1) single-valued items, such as numbers, letters, words, pictures, symbols, and codes; and (2) multivalued items, such as tables, curves, families of curves, equations, and nomographs.

Some examples of single-valued electronic-component data that the ECIC could handle are:

A. Numbers - 10 megacycles; 200 volts; 45% relative humidity; 3.25 inches (Figure 3a)

B. Letters - DC (direct current); UHF (ultra-high frequency); CW (continuous wave) (Figure 3a)

C. Words - Yes; No; Fixed; Variable; Tapped (Figure 3b)

D. Symbols - (Figure 3c)

E. Pictures - (Figure 3d)

F. Codes - CC (ECIC code for capacitors, for example, Figure 4, Column 3). Codes may be used with any of the above forms of data. They are required when recording pictures and symbols (with the exception of the few symbols which may be punched directly). A discussion of coding and classification may be found on pages 30 to 41. A complete set of ECIC codes is contained in the special ECIC Code Book issued June 15, 1951, and revised March 30, 1954.

Some examples of multivalued data are:

A. Tables of data - (Figure 3e)

B. Curves -
   Arithmetical Coordinates - (Figure 3f)
   Semilogarithmic Coordinates - (Figure 3g)
   Logarithmic Coordinates - (Figure 3h)
   Polar Coordinates - (Figure 3i)
   Trilinear Coordinates - (Figure 3j)

C. Systems of Curves -

Families of curves - (Figure 3k)

Fitted curves, with confidence limits - (Figure 3l)

Quality-control charts - (Figure 3m)

D. Equations (Figure 3n) and Nomograms - These forms may also be shown as curves or tables.

More than one method of recording may be applicable to some of the above forms of electronic data. The method which presents data in the most usable form should be employed. The methods employed in the ECIC have been specified in the ECIC data sheets for recording particular characteristics.

Examples showing in detail how the various forms of data listed above may be entered on IBM punched cards are contained in Phase Report No. 1, in two sections beginning with pages 7 and 75, respectively.

FORMS OF ELECTRONIC-COMPONENT DATA

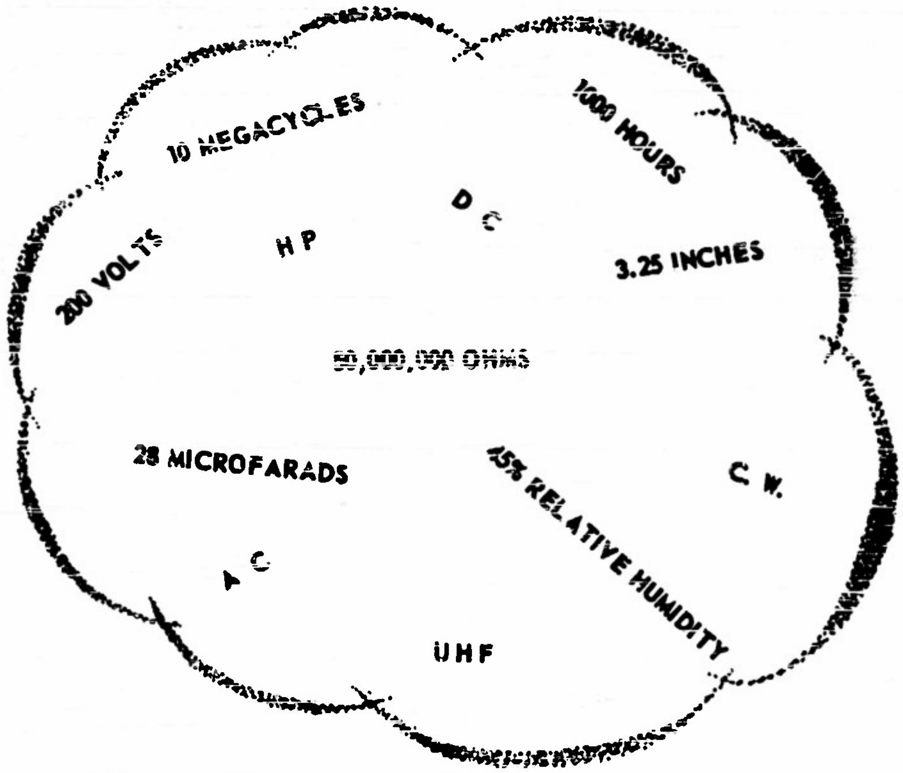


FIGURE 3a. NUMBERS AND LETTERS

CODE	WORDS
1	YES
2	NO
3	FIXED
4	VARIABLE
5	TAPPED

FIGURE 3b. WORDS

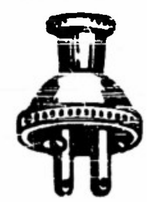
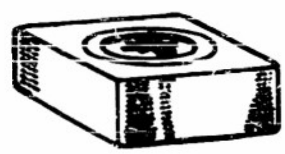
CODE 5	TERMINAL TYPE
55	 COAXIAL FITTING, MALE
56	 COAXIAL FITTING, FEMALE
57	 ATTACHMENT CAP
58	 ATTACHMENT CAP SOCKET

FIGURE 3d. PICTURES

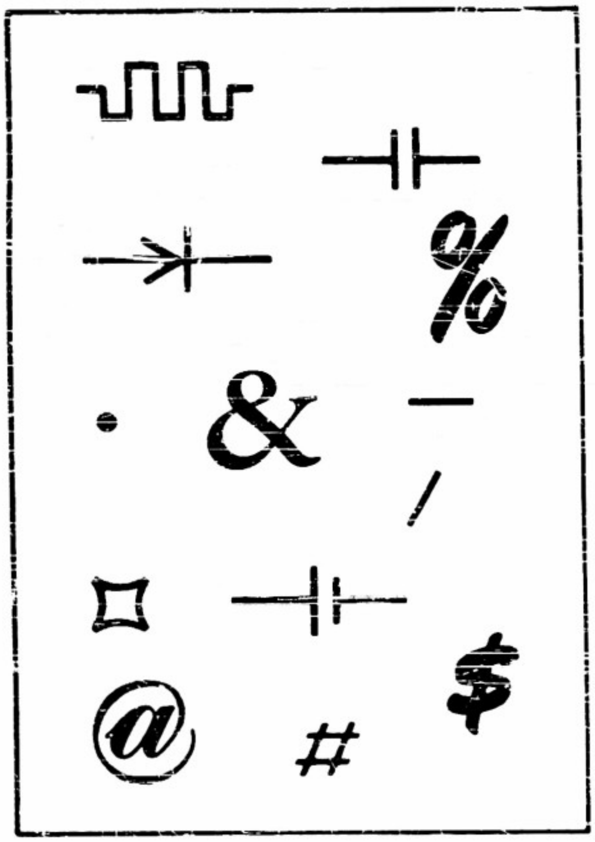


FIGURE 3c. SYMBOLS

Type	Maximum Power, continuous watts (WM)	Ohmic Value			Dimensions, inches					Maximum Continuous Voltage (VM)
		Min		Max						
		10% Tol.	5% Tol.		d	D	L	A	B	
B70	27	2	20	40k	5/16	5/8	2	5/32	11/16	400
B71	74	1	20	100k	3/8	7/8	3 1/2	3/8	15/16	700
B72	115	2	20	100k	3/8	7/8	4 1/2	3/8	15/16	1,000
B73	180	3	20	100k	3/8	7/8	6 1/2	3/8	15/16	1,800
B74	200	2	20	100k	5/8	1 1/8	6 1/2	3/8	1 1/8	1,800
B75	280	3	20	100k	5/8	1 1/8	8 1/2	3/8	1 1/8	2,500

FIGURE 3e. TABLE OF DATA, SHOWING RESISTOR DIMENSIONS AND CHARACTERISTICS

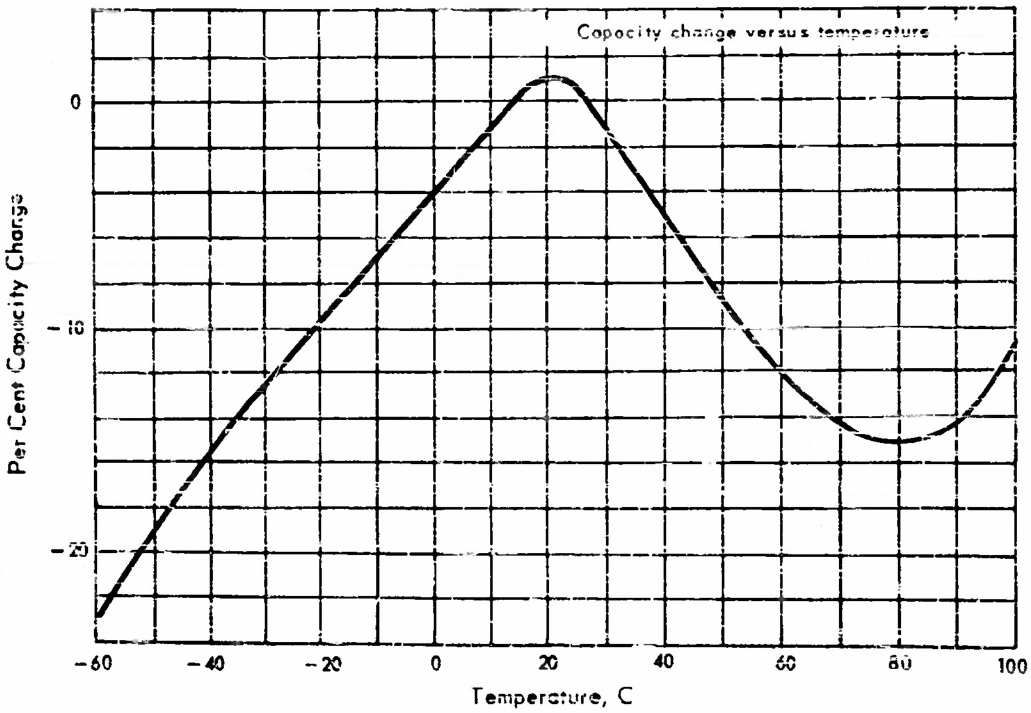


FIGURE 3f. CURVE--ARITHMETICAL COORDINATES, SHOWING HOW CAPACITY CHANGES WITH TEMPERATURE

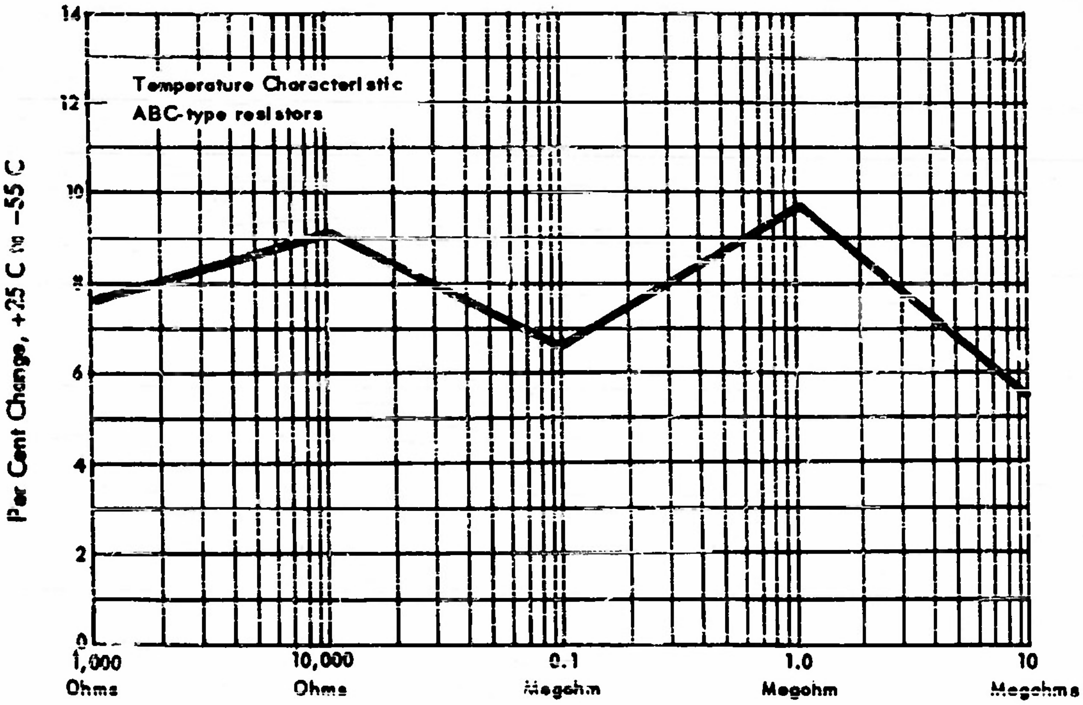


FIGURE 3a. CURVE–SEMILOGARITHMIC, SHOWING HOW RESISTOR TEMPERATURE CHARACTERISTIC VARIES WITH RESISTANCE

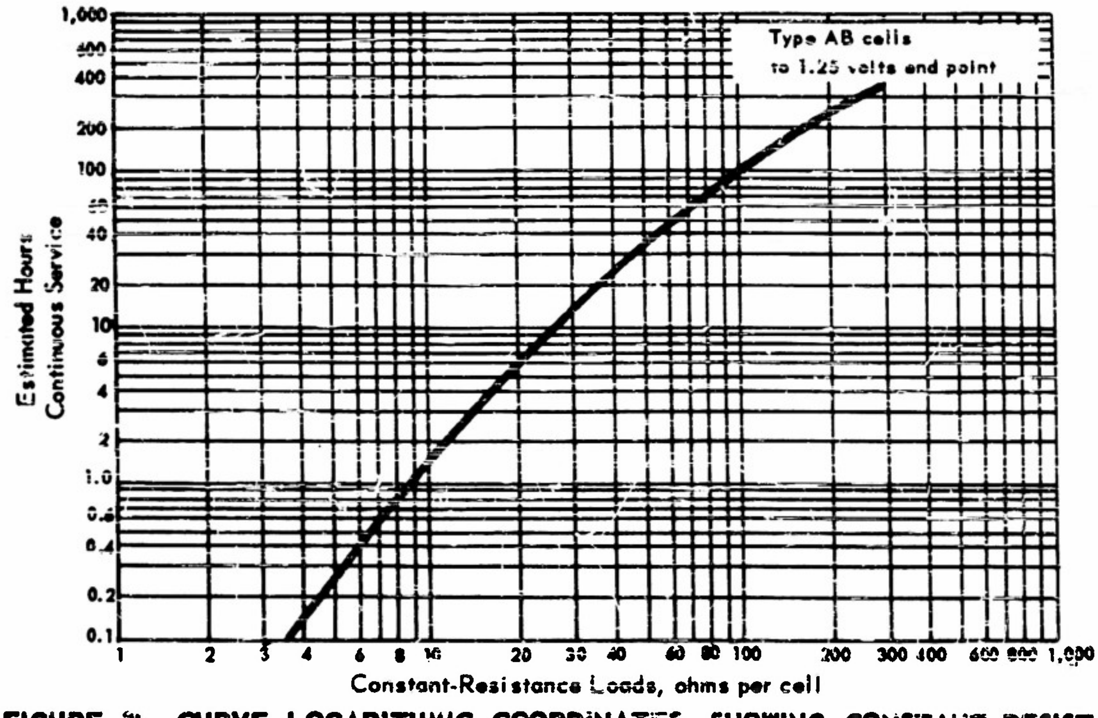


FIGURE 3b. CURVE–LOGARITHMIC COORDINATES, SHOWING CONSTANT-RESISTANCE DISCHARGE CURVE FOR SIZE "C" DRY CELLS

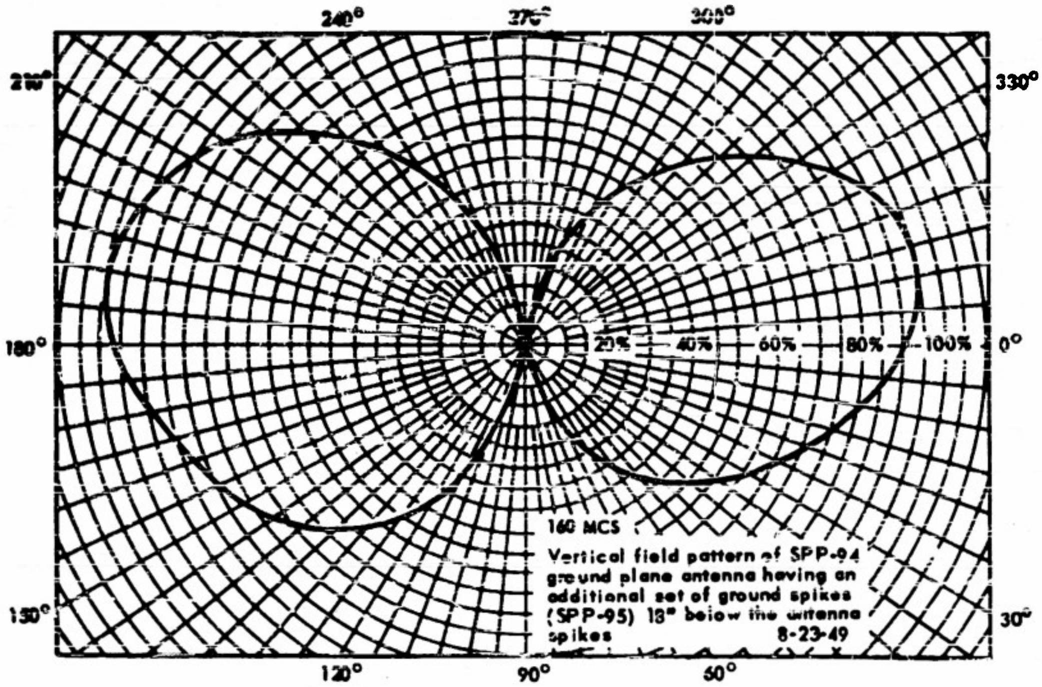


FIGURE 31. CURVE — POLAR COORDINATES, SHOWING ANTENNA FIELD PATTERN

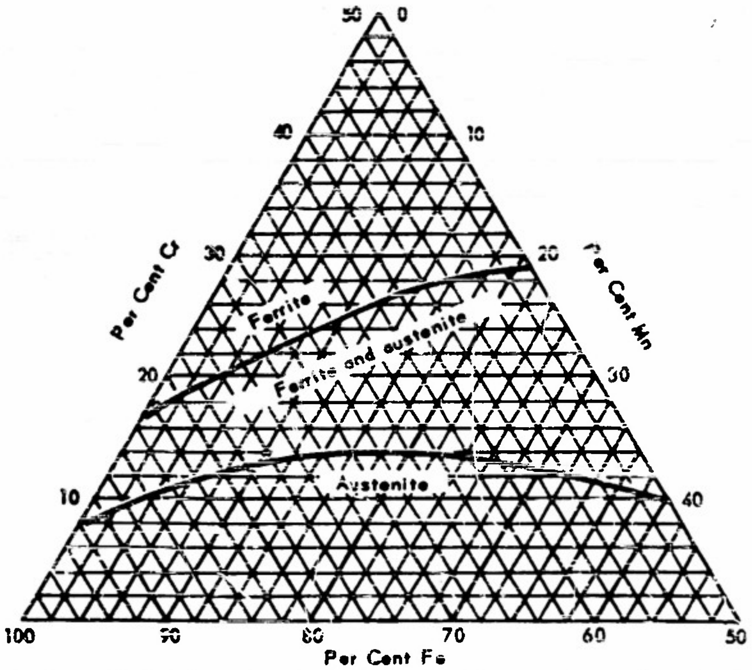


FIGURE 31. CURVES — TRILINEAR COORDINATES, SHOWING METALLOGRAPHIC PHASES PRESENT IN Fe-Mn-Cr ALLOYS

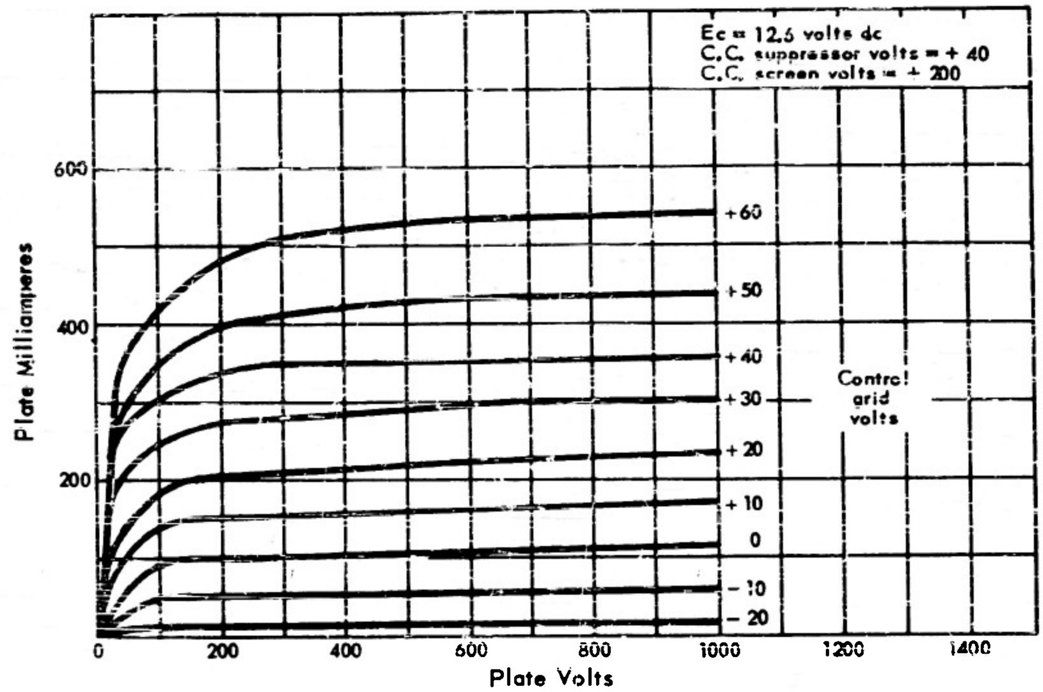


FIGURE 3k. FAMILIES OF CURVES, SHOWING TUBE CHARACTERISTICS FOR VARIOUS CONTROL GRID VOLTAGES

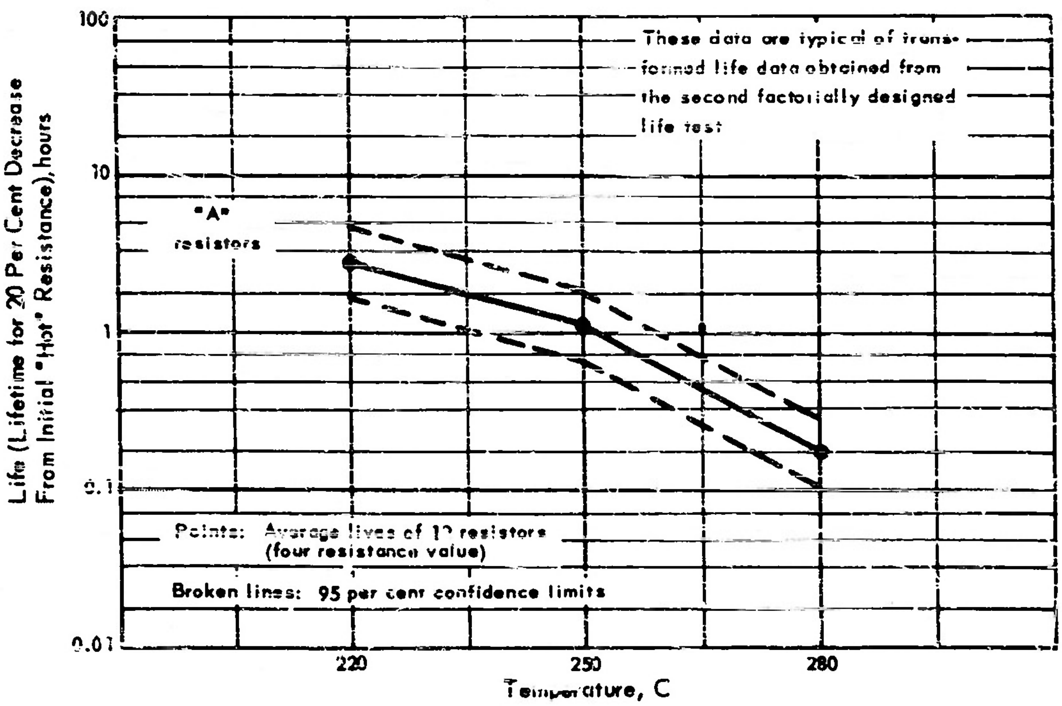


FIGURE 3l. CURVE-FITTED, WITH CONFIDENCE LIMITS, SHOWING HOW RESISTOR LIFE VARIES WITH TEMPERATURE

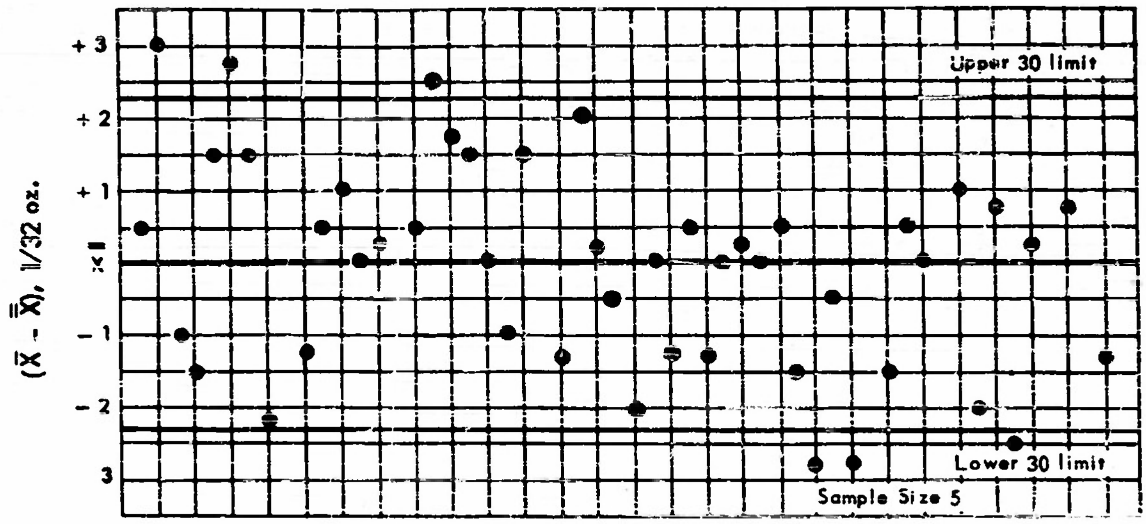


FIGURE 3m. CHART-QUALITY CONTROL, SHOWING VARIATION OF WEIGHTS IN PRODUCTION OF COMPONENTS

$$y = ax^2 + bx + c$$

FIGURE 3n. EQUATIONS

Collecting and Processing Input Data

There are many important problems associated with the actual collection of data for the ECIC. Since these problems have been explored only slightly, and then mainly to provide catalogue data sufficient for testing the technical aspects of the system, they are not discussed here as part of the description of the system, but are discussed in Part II of this report. The present section merely outlines the steps required in order to collect and process data for the ECIC.

Sources of Data

The value of sources of data for the ECIC would be governed largely by the quality of data they contain. Government, private, and industrial laboratories and testing facilities may provide useful data. Other sources may be reports of field, storage, and service organizations responsible for the use, storage, and maintenance of equipment. Information may also be obtained from technical societies and other organizations having an interest in electronic components and equipment.

Communication of Input Data to the ECIC

It is expected that, after an ECIC system had been in operation long enough to have become an accepted tool for the electronics industry, data would be submitted on a routine basis. Prior to that time, active efforts to procure data would be a regular function of the ECIC staff.

Input data may be received by the ECIC from the many sources indicated above and by nearly all means of communication. The information may come by mail, telegraph, teletype, telephone, and through personal visits. Among the forms in which the data would be received are:

(1) Catalogues

(2) Letters

(3) Design data sheets, blueprints, parts lists

(4) Specifications

(5) Engineering reports

(6) Test reports

(7) Field performance tests.

Screening of Data

Probably the most exacting job of the ECIC coordinating engineer* is the screening of the input data. Only valid data should be inserted in the ECIC punched-card files. Data from unidentified or questionable sources, data obtained through unknown or unproven tests, and conflicting data must be screened carefully. Data which "just don't look right" must be double checked, and discarded if they cannot be verified. Only after careful screening and checking should the ECIC engineers accept data for insertion into the files. A perpetual objective of the ECIC engineer should be to improve the quality of the data in the files.

Encoding and Transcribing Data to the ECIC Data Sheets

The ECIC system requires that many of the data stored in its files be coded in order to utilize efficiently the space available on punched cards. In order to enter data on punched cards, special data sheets** and codes have been devised. These codes and data sheets are the key to converting "raw data" into a form suitable for punching into cards. Pages 30 to 41 describe the classification and coding systems.

The data, as received from a source, are shown in the second column from the left of a typical data sheet under the heading "Insert Known Data Here". They are converted into the characters shown in the right-hand column headed "Value". These "value" items are the ones punched into the cards. Engineering judgment is required in order to select the "known data" suitable for insertion into the ECIC system. Actual conversion of data from the "known data" form into the "value" form may be done by a trained technician.

Punching of Cards

Card punching is a routine operation performed by a trained card-punch operator on a key punch. The operator merely transfers the data from the "Value" column on the data sheet to the proper punched-card columns.

Since the data for a single component will require a number of cards, different colors of cards may be used for Card No. 1, Card No. 2, Card No. 3, etc. This will aid in selecting the files to be searched and in card handling.

*The coordinating engineer would be the individual responsible for the technical proficiency of the operations.
**Detailed explanation of ECIC data sheets is contained in Part IV of Phase Report No. 1. Typical data sheets (for capacitors) may be found in this report, pages 45 to 91.

When some of the information called for on a standard data sheet is missing, the appropriate card columns are left blank. Then, should these data arrive later, they can be punched in the blank spaces.

When many of the data to be punched into a set of cards are identical on all the cards, the automatic duplicating features of the card punch can be utilized to speed up the operation. Careful analysis of the data to be punched will show the proper technique for accomplishing the task most efficiently.

Verifying Punching

Being a human operation much like typing, the punching of cards is subject to a certain amount of error. It is necessary, therefore, that each card's punching be verified before the card is placed in the permanent files. A number of ways of doing this, including some using machines, are:

(1) To check visually each punched card against the data sheet from which it was punched. This method is time-consuming and is not very accurate.

(2) To have each of two operators punch separate sets of cards and compare the two sets by means of the collator (or reproducer, if available)

(3) To use a card verifier, if available, instead of punching a second set of cards. The manual operation would be identical with that of card punching, but the second set of cards would be saved.

(4) To tabulate the data from a set of cards with a tabulating machine or Cardatype and compare the tabulated sheet with the original data.

The method to be used will be determined by the type and amount of data to be verified — but verification is essential.

Copy of ECIC Data to be Sent to Source

A conclusive check of the accuracy of data inserted into the ECIC files may be obtained by sending a copy of the data, tabulated from the ECIC cards, to the original sender of the data. In this way, errors that may have been made by the sender, as well as errors that have been made by the ECIC staff, could be detected.

Keeping Data Up to Date

Data sources should be encouraged to keep ECIC information current without prompting. At regular intervals, probably every six months, these sources should be contacted for information as to new products, discontinued products, and for additional or revised data on existing products. At least every ten years (perhaps oftener, if experience indicated the need), each file card should be reviewed and the data on it discarded or revised. The date of such revision would appear on the card.

Filing

After checking and correcting, cards are placed in the ECIC files. The cards are classified according to component group, type of component, and vertical-file breakdown (explanation starts on page 32). These classifications would establish the location of a card deck within the files. Within a card deck, the cards would remain in random order. Card color markings, corner cuts, and special printing make available over 1000 distinctive combinations to aid visual recognition and handling of the various card categories.

Space Required for Card Files

It is estimated that the data from all manufacturers on a typical component group (capacitors, for example) could be punched on about 100,000 IBM 80-column cards. This number of cards can be filed in one cabinet that would occupy floor space measuring 20 x 28 inches and be about 5 feet high. This means that, allowing for generous aisle space, a file room measuring about 15 x 20 feet probably would be large enough to house one complete file of cards on the 35 most extensively used electronic components.

Note: More detailed information concerning the insertion of data into the system may be found beginning on page 75 of Phase Report No. 1.

Classification and Coding

Classification

A major objective of the program which led to the development of the ECIC system was to make electronic-component information readily available. Data had to be obtainable quickly and cheaply. Although the development of an information-classification system was not included in the original research objective, it soon became apparent that such a system would be necessary if the requirements of speed and economy were to be met.

The classification scheme devised for the ECIC system permits one to find a desired unit of information by searching only a part of the total in the files. The classification system gains speed for the searcher by organizing information and defining terms.

The classification scheme described in this section is not a classical one. The sole objective of its development was the very practical aim of providing electronic-component information speedily and economically.

The ECIC Classification Problem. In the pa ', attempts have been made to classify all human knowledge for the purposes of better understanding and recovery. To date, no such classification scheme has been wholly successful. This is understandable, since, to be successful, the scheme must include or make provision for all knowledge — past, present, and future. If an individual or organization were fortunate enough to have this knowledge, there is still some question of whether it actually could be classified in a single system suitable for all purposes.

The situation is not so hopeless, however, when a single purpose is the objective of the classification system. If the desired classification is limited to a specific field of knowledge, the task becomes quite feasible. Many classification systems have been devised, for restricted fields of knowledge and based on limited objectives, which have served their purpose well.

A classification system suitable for the ECIC must have:

(1) A predetermined location or "pigeon hole" for each unit of information that is to be stored in the ECIC file. Some consideration was given to putting information into a system in completely random order. The thought was that machines could search through a large volume of random information rapidly enough. However, during the development of the ECIC, no machine adequate to do this job was available on the market. It was decided, therefore, to use the most

appropriate available machines for the job and to adapt the system to the machines. A natural result of this decision was the adoption of fixed-field punch cards for storing data. The fixed fields provide "pigeon holes" that may be located directly, or nearly so, in a very short time.

(2) A means to provide quick access to large volumes of data covering many characteristics. The need for searching through large volumes of data was recognized. However, it was also recognized that, at times, answers would require the consideration of many separate characteristics. This means that sequential time-consuming searching of many separate locations might often be necessary. The classification system needed, therefore, must permit simultaneous searching over broad ranges and combinations of characteristics, as well as for specific details. To accomplish this, information was organized in a vertical-file breakdown to three levels. Below these levels, no classification was made.

(3) Definitions of components and terms. A major problem confronting the users of the ECIC and the people working with it will be to understand the words that are used. This is the common problem of semantics. It was found that the classification system could well serve also to define terms. The characteristics that a component possesses in reality define the component. The ECIC classification system has been based on this observation. This is contrary to the usual use of a classification system, where terms are defined first and then located in accordance with their definitions. The ECIC classification system has been so designed that a component that may be called by many names elsewhere can have but one designation in the ECIC.

(4) Expandability. It was assumed that the last word in component development has not yet been conceived. Certainly, many new components will appear in the future. It is important that the system be flexible enough to permit acceptance of such new ideas. It would be tragic indeed if the ECIC system were so rigid as to exclude new and useful information, when the main objective of the system is to make this type of information more readily available. The ECIC system, if it is to have lasting value, must be able to accommodate new and as yet unknown components.

(5) Preselection of component characteristics. The characteristics to be recorded must be selected, organized, and defined before the system can be operated. It has been the

intention of the ECIC-system engineers to work out these details to include specific types of information that are of value today. They tried also to provide for the future by including data of a general technical nature.

The ECIC Classification System. During early development of the system, a major problem was to define what is meant by "electronic component". The definition of this term was basic to the fulfillment of the contract, since the latter required that all electronic components be considered and included in the ultimate system. The definition of "electronic component", therefore, had to cover the intent of the contract, but obviously, it could not be so general as to include everything that had electrons in its make-up. The practical definition finally selected was:

> "An electronic component is any item that is used to construct and becomes a part of electronic equipment (subassemblies and package units are excluded)."

This definition, although not perfect, has served as a guide to help decide what should or should not be included in the ECIC. It provides a reasonable line of demarcation between electronic components and more complex units.

After the general field of electronic components was defined, it became necessary to define the meanings of the various words used to describe components. Words such as "rectifier", "crystal", and "motor" describe well-known components, but each of them may be interpreted in more than one way. As an example, crystals are frequently used as rectifiers, but they also may be used as motors, under certain interpretations of the word "motor". Therefore, all electronic components known to the engineers were classified according to a scheme, termed the Code for Components, which became the basic definition of component names used in the ECIC.

The Code for Components, Figure 4, contains approximately 80 different items, which have been coded, and each item may represent a component. Commonly used terms, such as electron tubes, have been divided into five or six separate components, such as electron tubes - vacuum, electron tubes - gaseous, photoelectric cells, cathode-ray tubes, etc. The classification of components by this code permits a useful description of all components. As an example, a capacitor (Code CC) is listed as a component that uses energy directly in the performance of its prime function and in which a movement of electric charges or current is inherent in its operation. It is further classified as a linear element in which the flow of charged particles is restricted to solid or liquid conductors. The specific definition for a capacitor considers it as a component that is intended to introduce capacitance into a circuit. For ECIC purposes, any component that meets the requirements outlined above would be a capacitor and would be identified by the code symbol CC.

ECIC Code For Components

The following outline forms a basic definition of the various electronic components. The definition of an "Electronic Component" is given first and defines the scope of the outline. All electronic components are broken down into three groups, depending upon an energy-utilization principle. Each of these three groups is further broken down into two subgroups. The subgrouping is dependent upon principles which are unique for each group.

Electronic Components

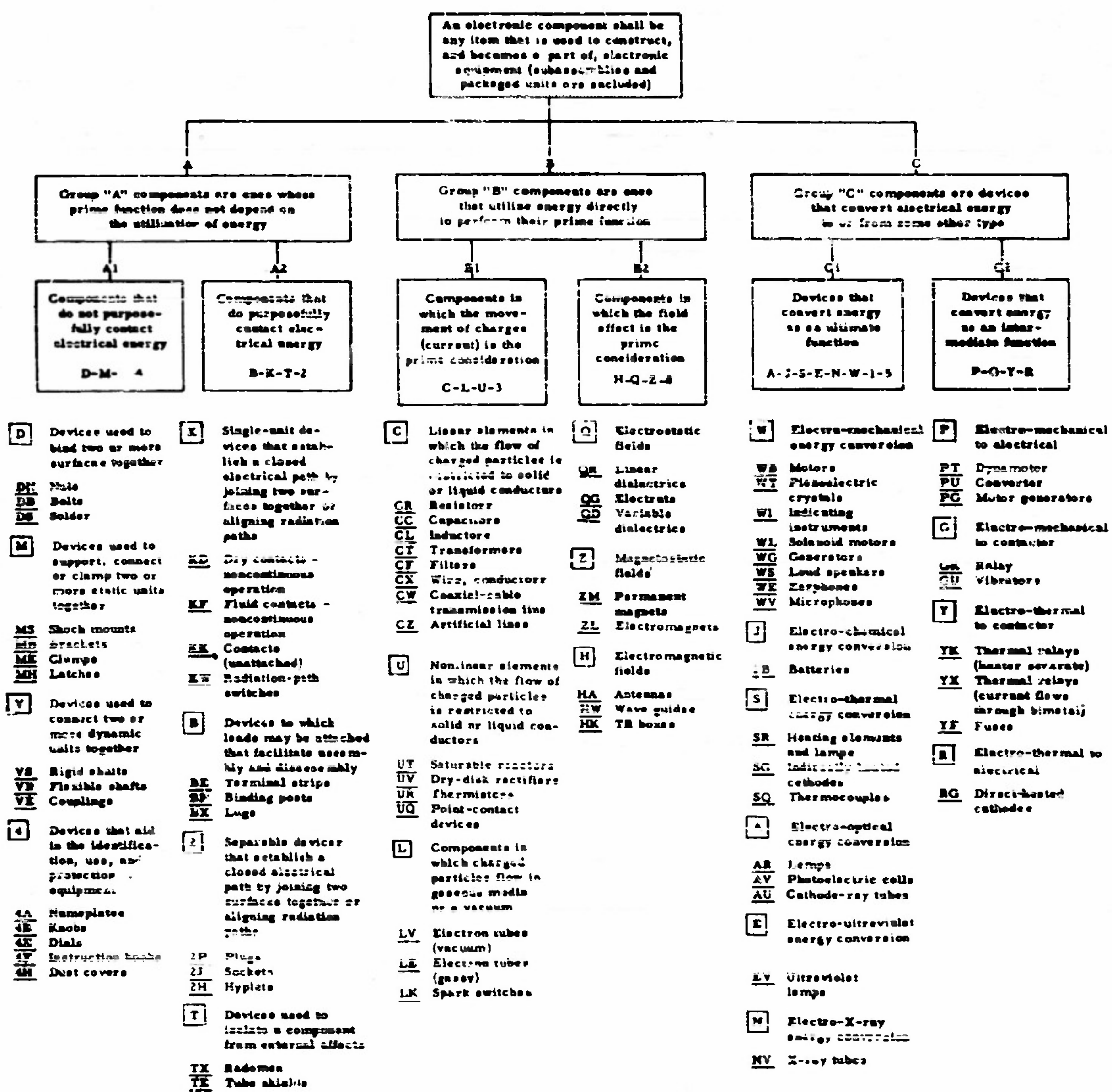


FIGURE 4. CODE FOR COMPONENTS

Symbols now in general usage were employed wherever possible. Standard symbols, however, could not always be used because of the characteristics of the IBM machine system. The machines require at least two symbols per component, and general usage does not always involve that number.

After the components had been defined, it was necessary to break down the component groups into types of component. An effort was made, for each component group, to find a natural breakdown by which more direct searching could be achieved.

Type of component has been defined, according to the ECIC system, as:

> "A division of the classification system which describes major differences of composition, construction, or function of a particular component. The basis of breakdown varies for each component and is defined separately for each component."

For capacitors, the type of component is based upon the dielectric material and the adjustability. Code No. 20, page 80, and the definitions pertaining to it show exactly what is meant by "type of component" for capacitors.

After completing this division, it was believed that still another breakdown would be required in order to keep the size of searches small. Therefore, a final breakdown was made. This has been called the vertical-file breakdown, and it has been defined as:

> "A subdivision of the classification system based on standard usage, construction differences, or operational characteristics of components. The basis of breakdown varies for each component and is defined separately for each component."

The vertical-file breakdown for capacitors, Code No. 21, page 81, is a subdivision of the classification system based on the operating voltage of the capacitor. There is no standard or fixed basis for making a vertical-file breakdown. The ultimate deciding factor as to which characteristic would be most useful for this purpose has been engineering judgment. The same vertical-file breakdowns have not necessarily been used for all of the various types of a given component. No further breakdowns were used beyond the vertical-file breakdown.

All components cards falling together after the vertical-file breakdown would be kept in random order, and searches through the randomized data made with a machine. This, in effect, has kept about 50 characteristics randomized, and the rigid classification system was applied only to three major characteristics: component, type of component, and the vertical-file breakdown.

The Special Reports and Code Books produced for the ECIC comprise the classification system. Understanding the ECIC classification system permits one to find the properties of any component in a very few minutes.

More detailed material on the classification system may be found in:

(1) Code Book dated June 15, 1951, revised March 30, 1954

(2) Phase Report No. 1, pages 7 through 15 and 47 through 82

(3) Interim Engineering Reports:

No. 1, pages 6 through 7
No. 3, pages 32 through 43
No. 4, pages 51 through 55a and 63 through 65
No. 5, pages 72 through 75
No. 6, pages 101 through 108 and 112 through 117
No. 7, pages 123 through 135 and 140 through 152
No. 8, pages 158 through 170 and 173 through 187
No. 9, pages 201 through 218
No. 10, pages 230 through 236 and 238 through 254
No. 11, pages 263 through 265 and 272 through 278
No. 12, pages 284 through 286 and 293 through 296

(4) Fifteen Special Reports (see the list on page 175)

Appendix B lists the above reports in more detail.

Coding

A code may be defined as "a system of symbols used for communication". These symbols may be words, letters, numbers, combinations of letters and numbers, or any reproducible signal or combination of signals. A representative code is the pattern of holes punched into IBM cards* to represent the letters of the alphabet, numbers, and eleven special characters used to record information. The letters, numbers, and special characters may be codes themselves, if direct recording of data is not feasible.

Codes may be used, in general, for two purposes. One is to conceal from unauthorized observers the meaning of information that must be transmitted. The ECIC is not concerned with codes for this purpose. The other purpose is to make the transmission (or communication) of information more efficient. All ECIC codes have been set up to provide efficient communication of data.

*This code is described in detail in Phase Report No. 1, page 18.

Reasons for Coding in ECIC. The ECIC codes were designed:

(1) To save space on cards. The limited space on a punched card (80 columns, with 12 punching positions per column) makes it imperative that information be recorded as concisely as practicable. By coding, it is possible to compress data into a smaller space than would be required for the uncoded data. A simple example is shown in Figure 5a. In that example, numbers that otherwise would require reserving 9 columns, such as 00000023.1 and 53200000.0, were reduced to four columns by coding them in the form of 2.31×10 and 5.32×10^7, recorded as 2311 and 5327.*

(2) To eliminate nonsignificant digits. The example of coding discussed above used numbers with many more digit positions than there were significant digits. It is very seldom that the number of significant digits required to record information exceeds four or five, and engineering data generally are not accurate to more than three significant digits. However, the range of values encountered frequently exceeds ten or twelve decimal positions. The range in resistance values, for example, may extend from below 0.001 ohm for shunts to over 10,000 megohms for high-meg resistors — a range of 14 decimal positions. Since only the significant digits and the location of the decimal point need be retained when data of this sort are stored, a code to indicate the decimal-point location aids condensation. This code is the simple exponential multiplier system mentioned previously.

(3) To simplify machine searching. Proper coding of information frequently makes a machine search easier. This will be true whenever the coded data more nearly approach the "language" of the machine than do the original data. Since most machines handle numbers more easily than letters, alphabetical information frequently can be coded into numerical form to simplify machine usage. It is possible, of course, to make a good machine code so complex that the gain in ease of machine usage does not justify the time required to translate the original data into coded form. Sound judgment should be exercised when developing codes, to ensure proper balance in the simplicity or complexity of the code.

*In a fixed-field system, enough columns must be reserved for the largest number it is desired to record. Therefore, if space for 53200000.0 is provided, it would be advisable to print the six ciphers in 00000023.1 even though only one might be needed.

(4) To record data that cannot be described in words. A Chinese proverb says that a picture is worth 10,000 words. Some pictures and some ideas cannot be described with words at all. However, symbols may be assigned to represent many ideas, and then those ideas, which may not be expressible in words, can be recorded on punched cards.

(5) To describe data precisely. Many words have a variety of, or uncertain, meanings. The problem of accurate communication becomes more difficult if words and items are not defined carefully. It is possible, in some cases, to eliminate the words and to resort entirely to codes in order to clarify the meanings intended for particular words by a particular user, such as the ECIC. An example of this type of coding was described in the previous section on Classification. This is the Code for Components, Figure 4, in which the code CC, for instance, represents what the ECIC system means by the word "capacitor". The Code for Components illustrates how a code and a classification scheme may supplement each other to define more precisely the words that have uncertain meanings in general usage.

What Can Be Coded? Any data that can be communicated can be coded. In fact, some things cannot be communicated unless they are coded, and the major communication channels, such as telephone, telegraph, radio, and television, always code the messages that pass over them. Most of the means used to record data in the ECIC involve coding of one sort or another. (This is in addition to the punched-hole code intrinsic to an IBM card.) Words, numbers, pictures, circuits, names and addresses, positions, ideas, and values have all been coded in the ECIC system.

The information coded is extensive. A separate volume of instructions, the Code Book*, was prepared to list, explain, and help interpret the information.

How is Information Coded? The methods of coding information used in the ECIC are described in the Code Book and on pages 75 through 82 of Phase Report No. 1.

Figure 5 shows examples of coding taken from those references. Among these are:

(1) Use of an exponential multiplier to eliminate unused digits (Figure 5a)

(2) Replacement of words and phrases with numbers (Figure 5b)

*Tentative Code Book for Electronic Component Information Center, originally issued in June, 1951; revised March 30, 1954.

5a.

Card space for number values is conserved in this manner:

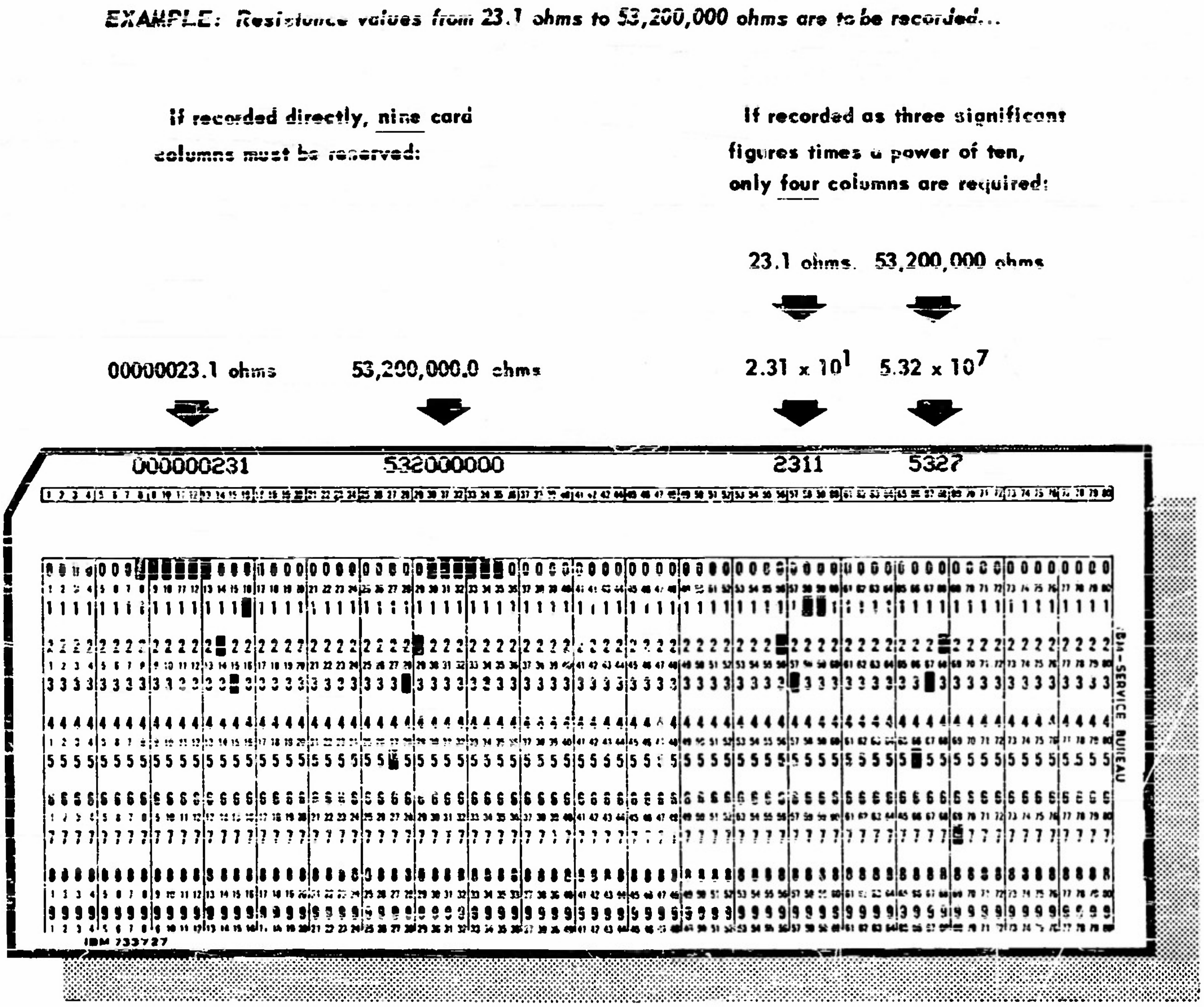


FIGURE 5. CODING METHODS

5b.

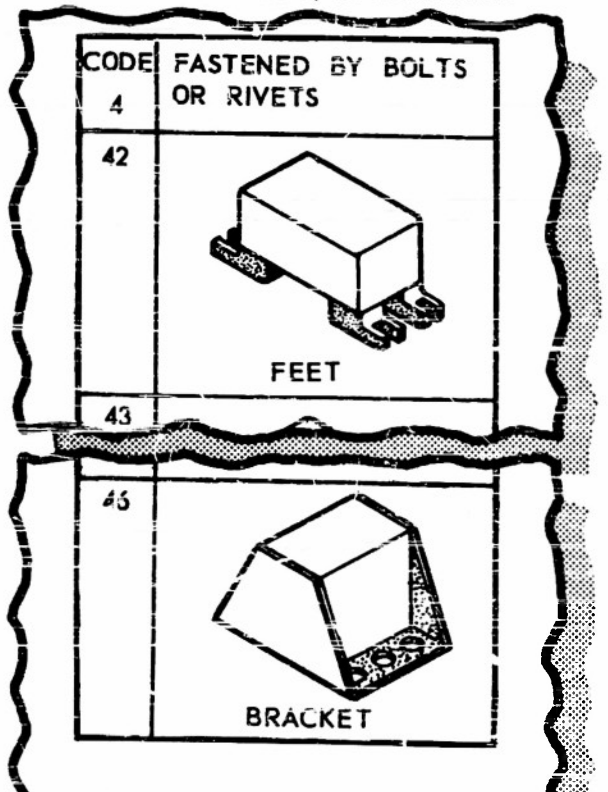
In this code, numbers are assigned to words and phrases. This permits one card column to carry all of the information listed:

Code	Type of Primary Batteries
1	Leclanche
2	Mercuric oxide
3	Caustic soda
4	Air Depolarized
5	Magnesium dry
6	Silver chloride
7	Vanadium pentoxide
8	Chlorine depolarized
0	Other types

ECIC BATTERY CODE

5d.

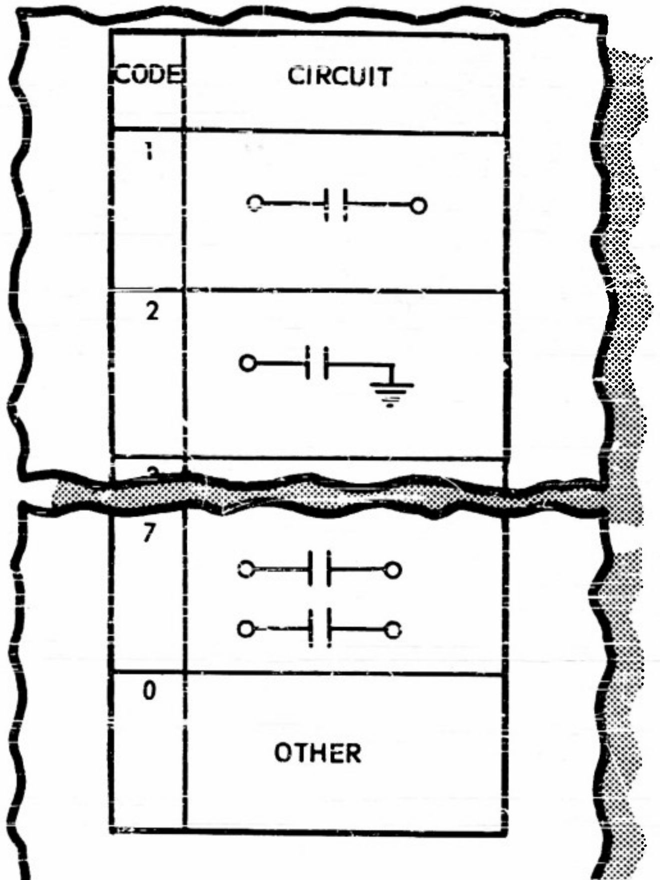
In this code, the Number 4 in thé first position indicates any mounting method that requires bolts or rivets for its use. The numbers in the second position (42, - - 46, etc;) indicate a particular type of the method (4) – such as feet or brackets, as illustrated:



PART OF ECIC MOUNTING METHOD CODE

5c.

In this code, a number is assigned to each specific circuit. The circuits are illustrated for positive identification:



ECIC CODE FOR INTERNAL CAPACITOR CIRCUITS

5e.

Manufacturers are coded in this manner:

RLRM............L. R. Maken Co., 527 Elm St., Newark, N. J.
KLPE............Lyon Paper Electric Co., 1251 Delancy St., San Diego, Calif.
SGTM............George Tompkins Mfg. Co., 245 N. St., Brooklyn, N. Y.
BAMC............Southern Electric Co., 5271 Paris Ave., Buffalo, N. Y.

ECIC CODE FOR MANUFACTURERS–ILLUSTRATIVE

The first letter of each of the codes represents the geographical area in which the plant is located. The last three letters are selected at random. A special listing of all of these codes is required.

(3) Representation of pictures, shapes, and circuits by means of numbers (Figures 5c and 5d)

(4) Classification of ideas by letters and numbers (Code for Components, Figure 4, Code for Manufacturers, Figure 5e). In these examples, a special categorical meaning is attached to the first symbol.

Decoding. All coded material must be decoded if it is to be understood. In many cases, codes are constructed systematically, and knowledge of the system will permit one to decode without a code book. In other cases, where no system exists, it is necessary that the total coded material be made available to permit decoding. The Code Book fills this need for the ECIC. All codes used in the ECIC are contained in it, and explained.

Data Sheets, Definitions, and Test Methods for Capacitors

Detailed data sheets, definitions, test methods, codes, and instructions for processing data on fifteen major electronic component groups have been incorporated into separate reports (see Appendix B), one for each group.

This section of the Final Report contains a reprint of the report for ECIC Work Sheets on Capacitors, as an example of the design details for processing component data in an ECIC.

Application-Data Sheets. The Application-Data Sheets for Capacitors, pages 45 through 64, include many of the significant single-valued and "continuously variable" characteristics of a capacitor. The single-valued data include such properties as pertinent ratings, physical properties (shape, dimension, etc.), type of enclosure, environmental conditions, and some electrical and mechanical characteristics. (Also included are continuously variable quantities, which include such data as operation under various conditions of humidity, altitude, temperature, and so forth.)

For the single-valued characteristics on the data sheets, definitions appear on the opposite page. The source from which the desired characteristic may be obtained for each item is included immediately following each definition. For the continuously variable-type data, the method for obtaining the data appears in the section, "ECIC Tentative Test Procedures for Capacitors".

Procurement-Data Sheets. In addition to replying to inquiries regarding the specific technical characteristics of capacitors, the ECIC may be asked to furnish limited information as to the procurement of the desired component. Procurement-data sheets, page 65, have been prepared to facilitate the entry of such information into the ECIC files in a uniform manner; definitions and sources of information accompany each item on the data sheet.

The procurement-data file of the ECIC can furnish information as to the manufacturer, stock and class numbers, and approximate cost of a particular capacitor. The corresponding Air Force stock and class numbers, as well as the type of approval granted to the capacitor, can also be given.

Summary-Data Sheets. In the interest of speedy service to the users of the ECIC, means have been devised to summarize certain data on

electronic components. This summary of information is possible because a number of manufacturers produce entire series of capacitors with many characteristics in common.

The basis on which capacitor data can be summarized is that the individual units are identical, except for capacitance range, weight, and miniaturization. Thus, the work sheets on pages 68 through 71 were prepared to permit the inclusion of the summary information and its conversion into a form suitable for entry into the ECIC files. Again, definitions for the characteristics are placed on the facing page, together with suitable sources for the individual items.

ECIC Tentative Test Procedures for Capacitors. This section, pages 72 to 79, contains the test methods for obtaining continuously variable data.

Existing military specifications have been used as the source of test methods by which these data may be obtained, wherever such specifications include suitable procedures. No military specification is applicable for obtaining some necessary information, and, in these cases, a tentative test procedure has been written. Such tentative procedures have not been proven on this project because of limited time and funds.

ECIC Capacitor Codes. This section, pages 80 to 82, contains the codes referring specifically to capacitors, and, together with the common codes Numbers 1 to 20 (see ECIC Code Book, June 15, 1951, revised March 30, 1954), forms the basis for encoding the technical characteristics of capacitors prior to their insertion into the ECIC files. Coding is required to condense the data to a form in which it can be readily entered on punched cards. Should additional codes be required at a later date, the code section may be expanded as needed.

Data-Collection Sheets for Capacitors. This section of the details on capacitors (pages 83 to 87) includes data sheets for use in collecting "raw" data. Space is provided for all technical information necessary for completing the application-data sheets. Definitions, instructions, and procedures are included or referenced to clarify any uncertainty as to how the blanks should be filled. These definitions, instructions, and procedures are similar to those provided for application-data sheets.

As in the application-data sheets, single-point and life-expectancy data are included as separate groups for convenience in handling.

These sheets have been prepared so that they can be filled in by a representative of a manufacturer or a testing laboratory, or by other persons not familiar with the ECIC system. They combine parts of the

ECIC application-data sheets with the ECIC codes to provide check-off lists wherever possible. In addition, definitions have been reworded somewhat to match the simplified data sheets. The test procedures referred to here are the same as those used with the application-data sheets.

Military Specifications for Capacitors

JAN-C- 5	Capacitors, Mica-Dielectric, Fixed
JAN-C- 20A	Capacitors, Fixed, Ceramic-Dielectric (Temperature-Compensating)
JAN-C- 25	Capacitors, Direct-Current, Paper-Dielectric, Fixed (Hermetically Sealed in Metallic Cases)
JAN-C- 62	Capacitors, Dry-Electrolytic, Polarized
JAN-C- 81	Capacitors, Ceramic-Dielectric, Variable
JAN-C- 91	Capacitors, Paper-Dielelectric, Fixed
JAN-C- 92	Capacitors, Air-Dielectric, Variable
MIL-C- 5623	Capacitor; Paper Foil, Power, 115-Volt Alternating Current, 400 to 2400 Cycles
MIL-C-10950A	Capacitors, Fixed, Mica-Dielectric, Button Styles
MIL-C-11015A	Capacitors, Fixed, Ceramic-Dielectric
MIL-C-11272	Capacitors, Fixed, Glass-Dielectric, Glass Case
MIL-C-11561	Capacitors, Suppression, High-Voltage
MIL-C-11693	Capacitors, Feed-Through
AAF-32412-B	Capacitors; Fixed

DETAILED WORK SHEETS

FOR CAPACITORS

Instruction Sheet for Application Data on Capacitors for Punched-Card File

1 October 1953

Card No. 1

Characteristics

I GENERAL

COMPONENT - Any capacitor that is used in the construction of, and becomes an integral part of, electronic equipment. A capacitor is a component which is designed to store or hold an electric charge. ECIC Code No. 1.

TYPE OF COMPONENT - A division of the ECIC classification system based on the degree of adjustability of the capacitor and the dielectric materials used in its construction. ECIC Code No. 20.
Source - Manufacturer's description.

VERTICAL-FILE BREAKDOWN - A subdivision of the ECIC classification system based on the working voltage rating of the capacitor.
Source - ECIC Code No. 21 and the working voltage rating of the capacitor. This value is shown under Pertinent Ratings.

INDEX CODE - A code which uniquely identifies the card or set of cards pertaining to one capacitor. ECIC Code No. 0.
Source - Issued by the ECIC controlling agency.

MANUFACTURER - The name of the firm which manufactures the capacitor. ECIC Code No. 2.

SPECIFICATIONS - A designation of the specifications the capacitor has passed in a manner acceptable to the agency issuing the specifications. ECIC Code No. 22.
Source - Manufacturer's data, MIL, JAN, or other specifications.

II PERTINENT RATINGS

CAPACITANCE - The nominal capacitance value of the capacitor. Capacitance is the ratio of charge to voltage. The units are micromicrofarads.
Source - Manufacturer's rating.

WORKING VOLTAGE - The nominal d-c working voltage which can be safely and continuously impressed across the capacitor terminals. The units are volts.
Source - Manufacturer's rating.

SECTION NUMBER - A number assigned to a section of a multiple-section capacitor to identify all punched-card data concerning that section. The sections are arranged according to voltage, with Section No. 1 being assigned to the lowest voltage section.
Source - Supplied by the ECIC.

III PHYSICAL

SHAPE - The shape as indicated by Shape Code No. 3 which gives the least volume and completely envelops the capacitor. The following apply:

(1) Leads and terminals which cannot be readily bent must be included in the shape.
(2) Mounting brackets that are an integral part of the structure must be included in the shape.

Source - Manufacturer's description or observation.

DIMENSIONS "A", "B", AND "C" - The dimensions of the capacitor as indicated by the Shape Code No. 3. The units for dimensions are mils.
Source - Manufacturer's description or direct measurement.

VOLUME - The volume as indicated by the shape and dimensions "A", "B", and "C". The units for volume are thousandths of a cubic inch.
Source - Calculated by ECIC.

MINIATURIZATION - A measure of the performance capability per unit volume. The nominal energy (micromicrowatt-seconds) per unit volume of the capacitor.
Source - Calculated by ECIC.

WEIGHT - The weight of the capacitor. The units for weight are milliounces.
Source - Direct measurement.

TERMINAL TYPE - The type of terminal used on the capacitor. ECIC Code No. 13.
Source - Observation.

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card No. 1

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
I General						
Component	Capacitor	--	2-3	2	1	CC
Type of component		--	4-5	2	20	
Vertical-file breakdown		--	6	1	21	
Index code		--	7-10	4	0	
Manufacturer		--	11-14	4	2	
Specifications		--	15-18	4	22	
II Pertinent Ratings						
Capacitance		00.1 x 10^N micromicrofarads	19-22	4	--	
Working voltage		0.1 x 10^N volts	23-25	3	--	
Section number		--	26	1	--	
III Physical						
Shape		--	27	1	3	
Dimension A		0.1 x 10^N mils	28-30	3	3	
Dimension B		0.1 x 10^N mils	31-33	3	3	
Dimension C		0.1 x 10^N mils	34-36	3	3	
Volume		0.1 x 10^N (.001 in.^{3})	37-39	3	3	
Miniaturization		01. x 10^N micromicrowatt-sec/(.001 in.^{3})	40-42	3	--	
Weight		.01 x 10^N milliounces	43-45	3	--	
Terminal type		--	46-47	2	13	

Characteristics

IV ENCLOSURE

CASE MATERIAL - The material used for the outside covering (exclusive of plating or finish) of the capacitor. ECIC Code No. 15.
Source - Manufacturer's data.

PROTECTIVE COVERING - The methods and materials used to protect the capacitor elements from their external environment. ECIC Code No. 4.
Source - Manufacturer's data.

FUNGUS INERT - The treatment of the capacitor against fungus. ECIC Code No. 5.
Test Procedure - MIL-E-5272, Paragraph 4.8.

CORROSION RESISTANCE - The corrosion resistance of the capacitor. ECIC Code No. 6.
Test Procedure - MIL-STD-202, Method 101.

V ENVIRONMENTAL

MAXIMUM AMBIENT TEMPERATURE OPERATIVE - The maximum sustained ambient temperature to which a capacitor can be subjected when not in operation, then be energized and operated within all specification limits.
Source - ECIC Test Procedure CC-Pl, Paragraph D-2. The maximum temperature for which operating life is 1000 hours.

MINIMUM AMBIENT TEMPERATURE OPERATIVE - The minimum sustained ambient temperature to which a capacitor can be subjected when not in operation, then be energized and operated within all specification limits.
Source - ECIC Test Procedure CC-Pl, Paragraph D-2. The minimum temperature for which operating life is 1000 hours.

MAXIMUM AMBIENT TEMPERATURE NONOPERATIVE - The maximum sustained ambient temperature to which a capacitor may be subjected when not in operation, and from which the capacitor may be returned to its normal operating temperature range and then be operated within all specification limits.
Source - ECIC Test Procedure CC-Pl, Paragraph D-2d. The maximum storage temperature for which shelf and operating lives are 1000 hours.

MINIMUM AMBIENT TEMPERATURE NONOPERATIVE - The minimum sustained ambient temperature to which a capacitor may be subjected when not in operation, and from which the capacitor may be returned to its normal operating temperature range and then be operated within all specification limits.
Source - ECIC Test Procedure CC-Pl, Paragraph D-2d. The minimum storage temperature for which shelf and operating lives are 1000 hours.

HUMIDITY - This refers to whether or not the capacitor has passed the humidity specifications of MIL-STD-202. ECIC Code No. 7.
Source - MIL-STD-202, Method 103.

ALTITUDE - This refers to whether or not the capacitor has passed the altitude specifications of MIL-STD-202. ECIC Code No. 8.
Source - MIL-STD-202, Method 105.

VIBRATION - This refers to whether or not the capacitor has passed the vibration specifications of MIL-STD-202. ECIC Code No. 9.
Source - MIL-STD-202, Method 201.

SHOCK - This refers to whether or not the capacitor has passed the shock specifications of MIL-STD-202. ECIC Code No. 10.
Source - MIL-STD-202, Method 202.

VI HISTORY

SHELF LIFE - The length of time a capacitor may be stored under standard conditions. At the end of this time, the capacitor must meet all specification requirements, including the minimum life expectancy. The units for shelf life are years.
Source - ECIC Test Procedure CC-Pl, Paragraph D-2d. Use life data obtained at 25 C.

SERVICE LIFE - The operating life in service that can be expected of a capacitor under normal operating conditions. The units for service life are hours.
Test Procedure - ECIC Test Procedure CC-Pl, Paragraph D-2. Life data obtained at 25 C indicate the service life of the capacitor.

QUARTER AND YEAR - The date on which a card is first prepared or completely reviewed and corrected. ECIC Code No. 11.
Source - Supplied by ECIC.

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

Card No. 1
(Continued)

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
IV <u>Enclosure</u>						
Case material	________	--	48-49	2	15	____
Protective covering	________	--	50-51	2	4	____
Fungus insert	________	--	52	1	5	____
Corrosion resistance	________	--	53	1	6	____
V <u>Environmental</u>						
Maximum ambient temperature operative	________	P/N 001. C	54-57	4	--	____
Minimum ambient temperature operative	________	P/N 001. C	58-61	4	--	____
Maximum ambient temperature nonoperative	________	P/N 001. C	62-65	4	--	____
Minimum ambient temperature nonoperative	________	P/N 001. C	66-69	4	--	____
Humidity	________	--	70	1	7	____
Altitude	________	--	71	1	8	____
Vibration	________	--	72	1	9	____
Shock	________	--	73	1	10	____
VI <u>History</u>						
Shelf life	________	01. years	74-75	2	--	____
Service life	________	.01 x 10^N hours	76-78	3	--	____
Quarter and year	________		79-80	2	11	____

Instruction Sheet for Application Data on Capacitors for Punched-Card File

1 October 1953

Card No. 2

Characteristics

COMPONENT - Any capacitor that is used in the construction of, and becomes an integral part of, electronic equipment. A capacitor is a component which is designed to store or hold an electric charge. ECIC Code No. 1.

TYPE OF COMPONENT - A division of the ECIC classification system based on the degree of adjustability of the capacitor and the dielectric materials used in its construction. ECIC Code No. 20.
Source - Manufacturer's description.

VERTICAL-FILE BREAKDOWN - A subdivision of the ECIC classification system based on the working voltage rating of the capacitor.
Source - ECIC Code No. 21 and the working voltage rating of the capacitor. This value is shown under Pertinent Ratings.

INDEX CODE - A code which uniquely identifies the card or set of cards pertaining to one capacitor. ECIC Code No. 0.
Source - Issued by the ECIC controlling agency.

SECTION NUMBER - A number assigned to a section of a multiple-section capacitor to identify all punched-card data concerning that section. The sections are arranged according to voltage, with Section No. 1 being assigned to the lowest voltage section.
Source - Supplied by ECIC.

VII ELECTRICAL

TOLERANCE, PLUS - The permissible plus deviation from the nominal value of capacitance. The units are per cent.
Source - Manufacturer's rating.

TOLERANCE, MINUS - The permissible minus deviation from the nominal value of capacitance. The units are per cent.
Source - Manufacturer's rating.

FREQUENCY RANGE OF APPLICATION - The frequency range over which the capacitor will remain within its nominal ratings under standard conditions. The units are cycles per second.
Test Procedure - ECIC Test Procedure CC-P1, Paragraph D-3.

VOLTAGE PEAK - The maximum instantaneous voltage that can be safely impressed across the terminals of a capacitor. The units are volts.
Test Procedure - ECIC Test Procedure CC-P1, Paragraph D-8.

VOLTAGE, AC - The nominal a-c voltage which can be safely and continuously impressed across the terminals of the capacitor over the entire frequency range of application under standard conditions. The units are volts.
Test Procedure - None available.

CIRCUIT - A schematic representation of the physical relationship between the capacitor elements and its terminals. ECIC Code No. 24.
Source - Manufacturer's description.

VOLTAGE COEFFICIENT OF CAPACITANCE - The parts per million change in capacitance per volts change in voltage across the terminals of the capacitor. ECIC Code No. 25.
Test Procedure - ECIC Test Procedure CC-P1, Paragraph D-4.

TEMPERATURE COEFFICIENT OF CAPACITANCE - The parts per million change in capacitance per degree (centigrade) change in temperature. ECIC Code No. 26.
Test Procedure - ECIC Test Procedure CC-P1, Paragraph D-2.

ABSORPTION - The amount of charge retained in the capacitor after the d-c working voltage has been applied for a fixed period of time and the capacitor then shorted for a fixed period of time. The units are micromicro-coulombs.
Test Procedure - ECIC Test Procedure CC-P1, Paragraph D-9.

DISSIPATION FACTOR - The ratio of the energy lost through leakage plus I^2R losses to the energy retained in the capacitor. The units are per cent.
Test Procedure - ECIC Test Procedure CC-P1, Paragraph D-10.

ENERGY ($1/2CE^2$) - The energy stored in a capacitor of "C" mmf capacitance when its rated voltage "E" is applied across its terminals. If a capacitor has more than one section, the value given is for the section being described. The units are microwatt-seconds.
Source - Calculated by ECIC.

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card No. 2

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Component	Capacitor	--	2-3	2	1	CC
Type of component		--	4-5	2	20	
Vertical-file breakdown		--	6	1	21	
Index code		--	7-10	4	0	
Section number		--	11	1	--	
VII <u>Electrical</u>						
Tolerance, plus		00.1%	12-14	3	--	
Tolerance, minus		00.1%	15-17	3	--	
Frequency range of application		01. $\times 10^N$ to 01. $\times 10^N$ cycles/sec	18-23	6	--	
Voltage peak		0.1×10^N volts	24-26	3	--	
Voltage, AC		0.1×10^N volts	27-29	3	--	
Circuit		--	30	1	24	
Voltage coefficient of capacitance		--	31-32	2	25	
Temperature coefficient of capacitance		--	33-34	2	26	
Absorption		0.1×10^N micromicrocoulombs	35-37	3	--	
Dissipation factor		$.01 \times 10^N$%	38-40	3	--	
Energy ($1/2CE^2$)		0.1×10^N microwatt-sec	41-43	3	--	

CIRCUIT INDUCTANCE - The self-inductance of the capacitor. The units are microhenries.
Test Procedure - None available.

CORONA VOLTAGE - The voltage across the terminals of the capacitor at which ionization begins to occur in the dielectric. The units are volts.
Test Procedure - None available.

RESONANT FREQUENCY - The frequency at which the impedance between the terminals reaches a minimum (or becomes resistive) value. The units are cycles per second.
Test Procedure - None available.

VOLTAGE INSULATION - The maximum d-c voltage which can be impressed across the shorted terminals of the capacitor and the case before damage occurs. The units are volts.
Test Procedure - None available.

INSULATION RESISTANCE - The resistance measured between the shorted terminals of the capacitor and the case. The units are megohms.
Test Procedure - Mica dielectric, fixed -- JAN-C-5, Paragraph F-2e; air dielectric, variable — JAN-C-92, Paragraph F-13; ceramic dielectric, fixed — JAN-C-20A, Paragraph F-8; ceramic dielectric, variable — JAN-C-81, Paragraph F-9; paper dielectric, fixed — JAN-C-91, Paragraph F-7; paper dielectric, fixed and hermetically sealed — JAN-C-25, Paragraph F-7; dry-electrolytic dielectric — JAN-C-62, Paragraph F-18.

VIII MECHANICAL

NUMBER OF TERMINALS - The exact number of terminals which extend from a capacitor.
Source - Observation.

MOUNTING METHOD - The manner in which the capacitor is to be attached to any assembly. ECIC Code No. 12.
Source - Observation.

TERMINAL ARRANGEMENT - The surface through which the terminals of the capacitor are extended. ECIC Code No. 14.
Source - Observation.

IX MISCELLANEOUS

NUMBER OF SECTIONS - The total number of separate capacitors contained in the component.
Source - Manufacturer's description.

PROJECT COVERAGE - This item indicates whether or not a development project covering capacitors is in force. ECIC Code. No. 23.
Source - Electronic Components Laboratory, Wright-Patterson Air Force Base, or the Electronic Components Development Register.

QUARTER AND YEAR - The date on which a card is first prepared or completely reviewed and corrected. ECIC Code No. 11.
Source - Supplied by ECIC.

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

Card No. 2
(Continued)

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Circuit inductance	______	0.1×10^N microhenries	44-46	3	--	______
Corona voltage	______	$01. \times 10^N$ volts	47-49	3	--	______
Resonant frequency	______	$01. \times 10^N$ cycles/sec	50-52	3	--	______
Voltage insulation	______	$01. \times 10^N$ volts	53-55	3	--	______
Insulation resistance	______	0.1×10^N megohms	56-58	3	--	______
VIII Mechanical						
Number of terminals	______	--	59-60	2	--	______
Mounting method	______	--	61-62	2	12	______
Terminal arrangement	______	--	63-64	2	14	______
IX Miscellaneous						
Number of sections	______	--	65	1	--	______
Project coverage	______	--	66	1	23	______
Quarter and year	______	--	79-80	2	11	______

Instruction Sheet for Application Data on Capacitors for Punched-Card File

1 October 1953

Card No. 3

Characteristics

COMPONENT - Any capacitor that is used in the construction of, and becomes an integral part of, electronic equipment. A capacitor is a component which is designed to store or hold an electric charge. ECIC Code No. 1.

TYPE OF COMPONENT - A division of the ECIC classification system based on the degree of adjustability of the capacitor and the dielectric materials used in its construction. ECIC Code No. 20.
Source - Manufacturer's description.

VERTICAL-FILE BREAKDOWN - A subdivision of the ECIC classification system based on the working voltage rating of the capacitor.
Source - ECIC Code No. 21 and the working voltage rating of the capacitor. This value is shown under Pertinent Ratings.

INDEX CODE RANGE - A set of code numbers which uniquely identifies the cards pertaining to the capacitors for which application data are summarized. ECIC Code No. B.
Source - Issued by ECIC controlling agency.

SECTION NUMBER - A number assigned to a section of a multiple-section capacitor to identify all punched-card data concerning that section. The sections are arranged according to voltage, with Section No. 1 being assigned to the lowest voltage section.
Source - Supplied by ECIC.

LIFE-CURVE TOLERANCES

Dissipation Factor - The allowable variation in dissipation factor of a capacitor. This value determines the useful life of the capacitor in the following life tests. The units are per cent.
Source - Supplied by ECIC.

Leakage Resistance - The allowable variation in leakage resistance of a capacitor. This value determines the useful life of the capacitor in the following life tests. The units are megohms.
Source - Supplied by ECIC.

Capacitance Change - The allowable variation in capacitance of a capacitor. This value determines the useful life of the capacitor in the following life tests. The units are per cent.
Source - Supplied by ECIC.

QUARTER AND YEAR - The date on which a card is first prepared or completely reviewed and corrected. ECIC Code No. 11.
Source - Supplied by ECIC.

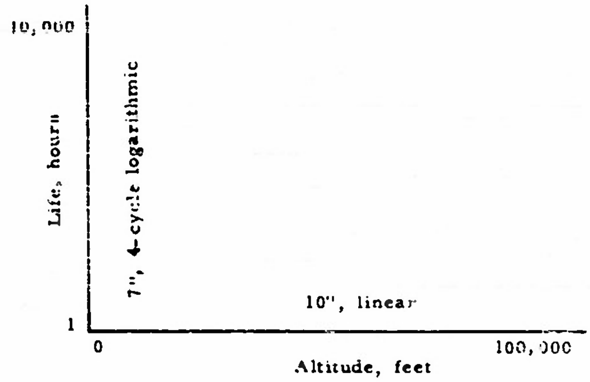
APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card No. 3

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Component	Capacitor	--	2-3	2	1	CC
Type of component	________	--	4-5	2	20	____
Vertical-file breakdown	________	--	6	1	21	____
Index code range	________	--	7-14	8	0	____
Section number	________		15	1	--	____
Life-curve tolerances	________					
Dissipation factor	________	.01 x 10^{N}%	19-21	3	--	____
Leakage resistance	________	0.1 x 10^{N} megohms	22-24	3	--	____
Capacitance change	________	.01 x 10^{N}%	25-27	3	--	____
Curves: Life vs. altitude with 95% confidence limits	________	Hours vs. feet	29-76	48	--	See below
Quarter and year	________	--	79-80	2	11	____

LIFE VS. ALTITUDE WITH 95% CONFIDENCE LIMITS
(ECIC Test Procedure CC-P1, Paragraph D-1)



Curve: Life (dissipation factor) vs. altitude

Horizontal Coordinate: 10", linear.
8 values reported as follows:
4 at altitudes of 25,000, 50,000, 75,000, and 100,000 feet above sea level under standard test conditions in Columns 29 through 32;
4 at altitudes of 0, 25,000, 50,000, and 75,000 feet above sea level under conditions of 50 C and 95 to 100% relative humidity, in Columns 33 through 36.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 37 through 44.

(At standard conditions)					(At 50 C and 95 to 100% relative humidity)				
Life values Column No.	29	30	31	32	Life values Column No.	33	34	35	36
Confidence values Column No.	37	38	39	40	Confidence values Column No.	41	42	43	44

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

Card No. 3

(Continued)

Curve: Life (leakage resistance) vs. altitude

Horizontal Coordinate: 10", linear.
8 values reported as follows:
4 values at 25,000, 50,000, 75,000, and 100,000 feet above sea level under standard test conditions, in Columns 45 through 48;
4 values at 0, 25,000, 50,000, and 75,000 feet above sea level under conditions of 50 C and 95 to 100% relative humidity, in Columns 49 through 52.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 53 through 60.

(At standard conditions)					(At 50 C and 95 to 100% relative humidity)				
Life values / Column No.	45	46	47	48	Life values / Column No.	49	50	51	52
Confidence values / Column No.	53	54	55	56	Confidence values / Column No.	57	58	59	60

Curve: Life (capacitance change, %) vs. altitude

Horizontal Coordinate: 10", linear.
8 values reported as follows:
4 values at 25,000, 50,000, 75,000, and 100,000 feet above sea level under standard test conditions, in Columns 61 through 64;
4 values at 0, 25,000, 50,000, and 75,000 feet above sea level under conditions of 50 C and 95 to 100% relative humidity, in Columns 65 through 68.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale on 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 69 through 76.

(At standard conditions)					(At 50 C and 95 to 100% relative humidity)				
Life values / Column No.	61	62	63	64	Life values / Column No.	65	66	67	68
Confidence values / Column No.	69	70	71	72	Confidence values / Column No.	73	74	75	76

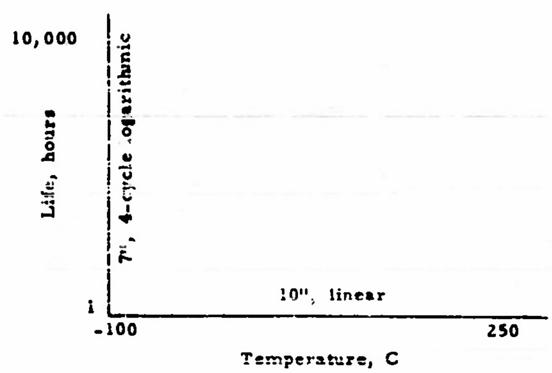
APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card No. 4

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Component	Capacitor	--	2-3	2	1	CC
Type of component		--	4-5	2	20	
Vertical file breakdown		--	6	1	21	
Index code range		--	7-14	8	0	
Section number		--	15	1	--	
Curves: Life vs. temperature with 95% confidence limits		Hours vs. C	19-78	60	--	See below
Quarter and year		--	79-80	2	11	

LIFE VS. TEMPERATURE WITH 95% CONFIDENCE LIMITS
(ECIC Test Procedure CC-P1, Paragraph D-2)



Curve: Life (dissipation factor) vs. temperature

Horizontal Coordinate: 10", linear. 10 values reported at temperatures of -100, -65, -35, 0, 25, 50, 100, 150, 200, and 250 C, in Columns 19 through 28.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 29 through 38.

Life values										
Column No.	19	20	21	22	23	24	25	26	27	28

Confidence values										
Column No.	29	30	31	32	33	34	35	36	37	38

Curve: Life (leakage resistance) vs. temperature

Horizontal Coordinate: 10", linear. 10 values reported at temperatures of -100, -65, -35, 0, 25, 50, 100, 150, 200, and 250 C, in Columns 39 through 48.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence values in Columns 49 through 58.

Life values										
Column No.	39	40	41	42	43	44	45	46	47	48

Confidence values										
Column No.	49	50	51	52	53	54	55	56	57	58

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

Card No. 4

(Continued)

Curve: Life (capacitance change, %) vs. temperature

Horizontal Coordinate: 10", linear, 10 values reported at temperatures of -100, -65, -35, 0, 25, 50, 100, 150, 200, and 250 C, in Columns 59 through 68.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence values in Columns 69 through 78.

Life values										
Column No.	59	60	61	62	63	64	65	66	67	68

Confidence values										
Column No.	69	70	71	72	73	74	75	76	77	78

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card No. 5

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Component	Capacitor	--	2-3	2	1	CC
Type of component		--	4-5	2	20	
Vertical-file breakdown		--	6	1	21	
Index code range		--	7-14	8	0	
Section number		--	15	1	--	
Curves: Life vs. frequency with 95% confidence limits		Hours vs. cycles per second	19-48	30	--	See below
Curves: Life vs. % rated working voltage with 95% confidence limits		Hours vs. volts	49-78	30	--	See below
Quarter and year		--	79-80	2	11	

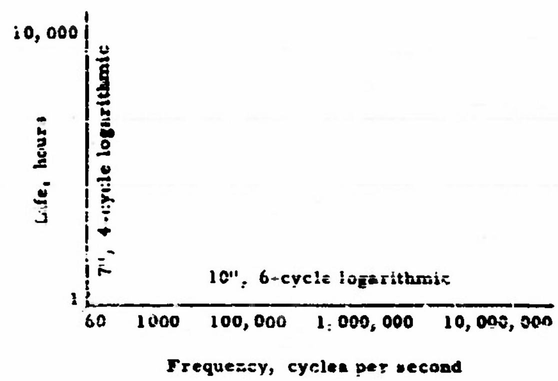
LIFE VS. FREQUENCY WITH 95% CONFIDENCE LIMITS
(ECIC Test Procedure CC-P1, Paragraph D-3)

Curve: Life (dissipation factor) vs. frequency

Horizontal Coordinate: 10", 6-cycle logarithmic. 5 values reported at frequencies of 60, 1000, 100,000, 1,000,000, and 10,000,000 cycles per second, in Columns 19 through 23.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 24 through 28.



Life values
Column No. ___ ___ ___ ___ ___
19 20 21 22 23

Confidence values
Column No. ___ ___ ___ ___ ___
24 25 26 27 28

Curve: Life (leakage resistance) vs. frequency

Horizontal Coordinate: 10", 6-cycle logarithmic. 5 values reported at frequencies of 60, 1000, 100,000, 1,000,000, and 10,000,000 cycles per second, in Columns 29 through 33.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 34 through 38.

Life values
Column No. ___ ___ ___ ___ ___
29 30 31 32 33

Confidence values
Column No. ___ ___ ___ ___ ___
34 35 36 37 38

Curve: Life (capacitance change, %) vs. frequency

Horizontal Coordinate: 10", 6-cycle logarithmic. 5 values reported at frequencies of 60, 1000, 100,000, 1,000,000, and 10,000,000 cycles per second, in Columns 39 through 43.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale on 7 x 10 Rectangular Grid No. 1.

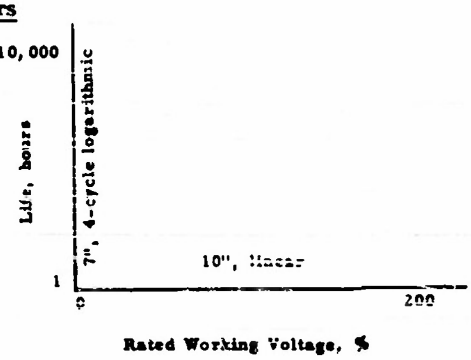
Use Confidence Limit Scale No. 4. Record confidence limits in Columns 44 through 48.

Life values
Column No. 39 40 41 42 43

Confidence values
Column No. 44 45 46 47 48

- -

LIFE VS. % RATED WORKING VOLTAGE WITH 95% CONFIDENCE LIMITS
(ECIC Test Procedure CC-P1, Paragraph D-4)



Curve: Life (dissipation factor) vs. % rated working voltage

Horizontal Coordinate: 10", linear. 5 values reported at 25, 50, 100, 150, and 200% rated working voltage, in Columns 49 through 53.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 54 through 58.

Life values
Column No. 49 50 51 52 53

Confidence values
Column No. 54 55 56 57 58

Curve: Life (leakage resistance) vs. % rated working voltage

Horizontal Coordinate: 10", linear. 5 values reported at 25, 50, 100, 150, and 200% rated working voltage, in Columns 59 through 63.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 64 through 68.

Life values
Column No. 59 60 61 62 63

Confidence values
Column No. 64 65 66 67 68

Curve: Life (capacitance change, %) vs. % rated working voltage

Horizontal Coordinate: 10", linear. 5 values reported at 25, 50, 100, 150, and 200% rated working voltage, in Columns 69 through 73.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale on 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 74 through 78.

Life values
Column No. 69 70 71 72 73

Confidence values
Column No. 74 75 76 77 78

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card No. 6

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Component	Capacitor	--	2-3	2	1	CC
Type of component		--	4-5	2	20	
Vertical-file breakdown		--	6	1	21	
Index code range		--	7-14	8	0	
Section number		--	15	1	--	
Curves: Life vs. vibration with 95% confidence limits		Hours vs. in.	19-42	24	--	See below
Curves: Life vs. shock with 95% confidence limits		Drops vs. G's	43-78	36	--	See below
Quarter and year		--	79-80	2	11	

LIFE VS. VIBRATION WITH 95% CONFIDENCE LIMITS
(ECIC Test Procedure CC-P1, Paragraph D-5)

Curve: Life (dissipation factor) vs. vibration

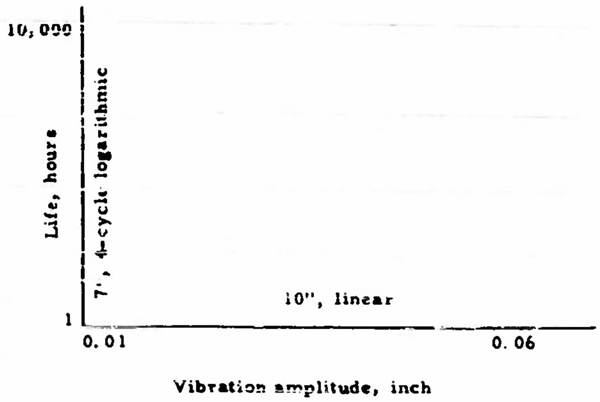
Horizontal Coordinate: 10" linear. 4 values reported at vibration amplitudes of 0.01, 0.02, 0.04, and 0.06 inch, in Columns 19 through 22.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 23 through 26.

Life values				
Column No.	19	20	21	22

Confidence values				
Column No.	23	24	25	26



Curve: Life (leakage resistance) vs. vibration

Horizontal Coordinate: 10", linear. 4 values reported at vibration amplitudes of 0.01, 0.02, 0.04, and 0.06 inch, in Columns 27 through 30.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 31 through 34.

Life values				
Column No.	27	28	29	30

Confidence values				
Column No.	31	32	33	34

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

Card No. 6

(Continued)

__Curve:__ Life (capacitance change, %) vs. vibration

Horizontal Coordinate: 10", linear. 4 values reported at vibration amplitudes of 0.01, 0.02, 0.04, and 0.06 inch, in Columns 35 through 38.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

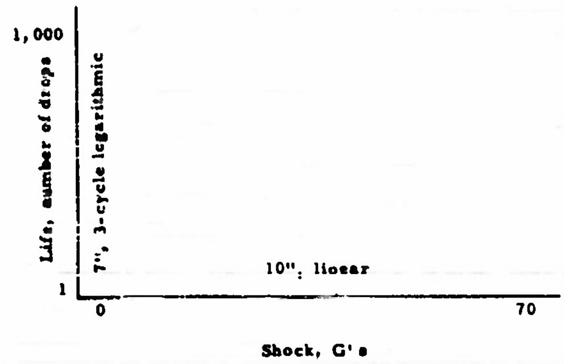
Use Confidence Limit Scale No. 4. Record confidence limits in Columns 39 through 42.

__Life values__
Column No. 35 36 37 38

__Confidence values__
Column No. 39 40 41 42

__LIFE VS. SHOCK WITH 95% CONFIDENCE LIMITS__
(ECIC Test Procedure CC-P1, Paragraph D-6)

__Curve:__ Life (dissipation factor) vs. shock



Horizontal Coordinate: 10", linear. 6 values reported at shock intensities of 2, 5, 10, 20, 40, and 70 G's, in Columns 43 through 48.

Vertical Coordinate: 7", 3-cycle logarithmic, 1 to 1,000 drops. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 49 through 54.

__Life values__
Column No. 43 44 45 46 47 48

__Confidence values__
Column No. 49 50 51 52 53 54

__Curve:__ Life (leakage resistance) vs. shock

Horizontal Coordinate: 10", linear. 6 values reported at shock intensities of 2, 5, 10, 20, 40, and 70 G's, in Columns 55 through 60.

Vertical Coordinate: 7", 3-cycle logarithmic, 1 to 1,000 drops. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 61 through 66.

__Life values__
Column No. 55 56 57 58 59 60

__Confidence values__
Column No. 61 62 63 64 65 66

__Curve:__ Life (capacitance change, %) vs. shock

Horizontal Coordinate: 10", linear. 6 values reported at shock intensities of 2, 5, 10, 20, 40, and 70 G's, in Columns 67 through 72.

Vertical Coordinate: 7", 3-cycle logarithmic, 1 to 1,000 drops. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 73 through 78.

__Life values__
Column No. 67 68 69 70 71 72

__Confidence values__
Column No. 73 74 75 76 77 78

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card No. 7

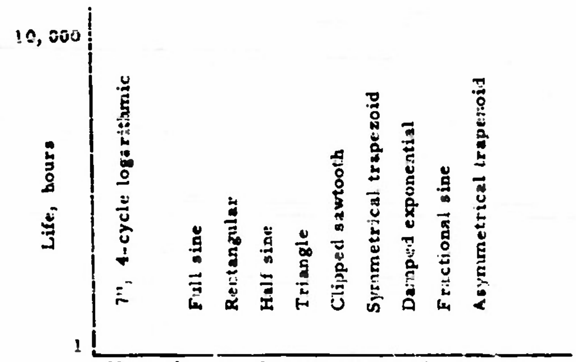
Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Component	Capacitor	--	2-3	2	1	CC
Type of component		--	4-5	2	20	
Vertical-file breakdown		--	6	1	21	
Index code range		--	7-14	8	0	
Section number		--	15	1	--	
Charts: Life vs. pulse type with 95% confidence limits		Hours vs. pulse type	19-72	54	--	See below
Curve: Voltage peak vs. temperature		Volts vs. C	73-76	4	--	See below
Quarter and year		--	79-80	2	11	

LIFE VS. PULSE TYPE WITH 95% CONFIDENCE LIMITS
(ECIC Test Procedure CC-P1, Paragraph D-7)

Curve: Life (dissipation factor) vs. pulse type

Horizontal Coordinate: List of 9 pulse types reported in columns as follows:

Pulse Type	Column No.
Full sine	19
Rectangular	20
Half sine	21
Triangle	22
Clipped sawtooth	23
Symmetrical trapezoid	24
Damped exponential	25
Fractional sine	26
Asymmetrical trapezoid	27



No scale: equally spaced list of indicated pulse types.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 28 through 36.

Life values Column No.	19	20	21	22	23	24	25	26	27
Confidence values Column No.	28	29	30	31	32	33	34	35	36

APPLICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

Card No. 7

(Continued)

Curve: Life (leakage resistance) vs. pulse type

Horizontal Coordinate: List of 9 pulse types reported in columne as follows:

Pulse Type	Column No.
Full sine	37
Rectangular	38
Half sine	39
Triangle	40
Clipped sawtooth	41
Symmetrical trapezoid	42
Damped exponential	43
Fractional sine	44
Asymmetrical trapezoid	45

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 46 through 54.

Life values									
Column No.	37	38	39	40	41	42	43	44	45

Confidence values									
Column No.	46	47	48	49	50	51	52	53	54

Curve: Life (capacitance change, %) vs. pulse type

Horizontal Coordinate: List of 9 pulse types recorded in columns as follows:

Pulse Type	Column No.
Full sine	55
Rectangular	56
Half sine	57
Triangle	58
Clipped sawtooth	59
Symmetrical trapezoid	60
Damped exponential	61
Fractional sine	62
Asymmetrical trapezoid	63

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 hours. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Use Confidence Limit Scale No. 4. Record confidence limits in Columns 64 through 72.

Life values									
Column No.	55	56	57	58	59	60	61	62	63

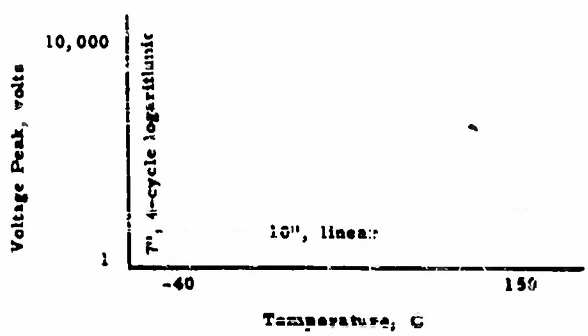
Confidence values									
Column No.	64	65	66	67	68	69	70	71	72

VOLTAGE PEAK VS. TEMPERATURE
(ECIC Test Procedure CC-P1, Paragraph D-8)

Horizontal Coordinate: 10", linear. 4 values reported at temperatures of -40, 25, 75, and 150 C, in Columns 73 through 76.

Vertical Coordinate: 7", 4-cycle logarithmic, 1 to 10,000 volts. Use vertical scale of 7 x 10 Rectangular Grid No. 1.

Values				
Column No.	73	74	75	76



PROCUREMENT DATA SHEETS

FOR CAPACITORS

Instruction Sheet for Procurement and Qualification Data on Capacitors for Punched-Card File

1 October 1953

Card [illegible]

Characteristics

I GENERAL

COMPONENT - Any capacitor that is used in the construction of, and becomes an integral part of, electronic equipment. A capacitor is a component which is designed to store or hold an electric charge. ECIC Code No. 1.

TYPE OF COMPONENT - A division of the ECIC classification system based on the degree of adjustability of the capacitor and the dielectric materials used in its construction. ECIC Code No. 20.
Source - Manufacturer's description.

VERTICAL-FILE BREAKDOWN - A subdivision of the ECIC classification system based on the working voltage rating of the capacitor.
Source - ECIC Code No. 21 and the working voltage rating of the capacitor. This value is shown under Pertinent Ratings.

INDEX CODE - A code which uniquely identifies the card or set of cards pertaining to one capacitor. ECIC Code No. 9.
Source - Issued by the ECIC controlling agency.

MANUFACTURER - The name of the firm which manufactures the capacitor. ECIC Code No. 2.

SPECIFICATIONS - A designation of the specifications the capacitor has passed in a manner acceptable to the agency issuing the specifications. ECIC Code No. 22.
Source - Manufacturer's data. MIL, JAN, or other specifications.

II PERTINENT RATINGS

CAPACITANCE - The nominal capacitance value of the capacitor. Capacitance is the ratio of charge to voltage. The units are micromicrofarads.
Source - Manufacturer's rating.

WORKING VOLTAGE - The nominal d-c working voltage which can be safely and continuously impressed across the capacitor terminals. The units are volts.
Source - Manufacturer's rating.

SECTION NUMBER - A number assigned to a section of a multiple-section capacitor to identify all punched-card data concerning that section. The sections are arranged according to voltage, with Section No. 1 being assigned to the lowest voltage.
Source - Supplied by ECIC.

III ASSIGNED NUMBERS

MFG'S TYPE NUMBER - The number assigned by the manufacturer to uniquely identify a particular class of capacitor.
Source - Manufacturer's data.

MFG'S PART NUMBER - The number assigned by the manufacturer to uniquely identify a particular capacitor.
Source - Manufacturer's data.

A. F. STOCK NUMBER - The number assigned by the Air Force to identify a capacitor as to capacitance and working voltage.
Source - U. S. Air Force.

A. F. CLASS NUMBER - The number assigned by the Air Force to identify capacitors.
Source - U. S. Air Force.

IV MISCELLANEOUS

APPROVAL TYPE - The type of approval granted to the capacitor. ECIC Code No. 17.
Source - Electronic Components Laboratory, Wright-Patterson Air Force Base.

DATE SAMPLE SUBMITTED - The date on which the capacitor sample is submitted for test. ECIC Code No. 11.
Source - Electronic Components Laboratory, Wright-Patterson Air Force Base.

DATE CERTIFIED TEST DATA SUBMITTED - The date on which the test data on a capacitor are submitted. ECIC Code No. 11.
Source - Electronic Components Laboratory, Wright-Patterson Air Force Base.

DATE APPROVED - The date on which the capacitor is approved. ECIC Code No. 11.
Source - Electronic Components Laboratory, Wright-Patterson Air Force Base.

DATE DISAPPROVED - The date on which the capacitor is disapproved. ECIC Code No. 11.
Source - Electronic Components Laboratory, Wright-Patterson Air Force Base.

COST PER UNIT - The approximate cost per individual capacitor.
Source - Manufacturer's data.

QUARTER AND YEAR - The date on which a card is first prepared or completely reviewed and corrected. ECIC Code No. 11.
Source - Supplied by ECIC.

PROCUREMENT AND QUALIFICATION DATA ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card F

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
I General						
Component	Capacitor	--	2-3	2	1	CC
Type of component		--	4-5	2	20	
Vertical-file breakdown		--	6	1	21	
Index code		--	7-10	4	0	
Manufacturer		--	11-14	4	2	
Specifications		--	15-18	4	22	
II Pertinent Ratings						
Capacitance		00.1 x 10^N micromicrofarads	19-22	4	--	
Working voltage		0.1 x 10^N volts	23-25	3	--	
Section number		--	26	1	--	
III Assigned Numbers						
Mfg's type number		--	27-36	10	--	
Mfg's part number		--	37-48	12	--	
A. F. stock number		--	49-61	13	--	
A. F. class number		--	62-66	5	--	
IV Miscellaneous						
Approval type		--	67	1	17	
Date sample submitted		--	68-69	2	11	
Date certified test data submitted		--	70-71	2	11	
Date approved		--	72-73	2	11	
Date disapproved		--	74-75	2	11	
Cost per unit		.01 x 10^N cents	76-78	3	--	
Quarter and year		--	79-80	2	11	

Instruction Sheet for Summary Data on Capacitors for Punched-Card File

1 October 1953

Card S

Characteristics

COMPONENT - Any capacitor that is used in the construction of, and becomes an integral part of, electronic equipment. A capacitor is a component which is designed to store or hold an electric charge. ECIC Code No. 1.

TYPE OF COMPONENT - A division of the ECIC classification system based on the degree of adjustability of the capacitor and the dielectric materials used in its construction. ECIC Code No. 20.
Source - Manufacturer's description.

VERTICAL-FILE BREAKDOWN - A subdivision of the ECIC classification system based on the working voltage rating of the capacitor.
Source - ECIC Code No. 21 and the working voltage rating of the capacitor. This value is shown under Pertinent Ratings.

INDEX CODE - A code which uniquely identifies the card or set of cards pertaining to one capacitor. ECIC Code No. 0.
Source - Issued by the ECIC controlling agency.

MANUFACTURER - The name of the firm which manufactures the capacitor. ECIC Code No. 2.

SPECIFICATIONS - A designation of the specifications the capacitor has passed in a manner acceptable to the agency issuing the specifications. ECIC Code No. 22.
Source - Manufacturer's data, MIL, JAN, or other specifications.

CAPACITANCE RANGE - The range of capacitance values for which the application data are summarized. The units are micromicrofarads.
Source - Manufacturer's rating.

WORKING VOLTAGE - The nominal d-c working voltage which can be safely and continuously impressed across the capacitor terminals. The units are volts.
Source - Manufacturer's rating.

TOLERANCE, PLUS - The permissible plus deviation from the nominal value of capacitance. The units are per cent.
Source - Manufacturer's rating.

TOLERANCE, MINUS - The permissible minus deviation from the nominal value of capacitance. The units are per cent.
Source - Manufacturer's rating.

MINIATURIZATION RANGE - The range of miniaturization values of the capacitors for which the application data are summarized. The units are micromicrowatt-sec/0.001 inch.
Source - Calculated by ECIC.

WEIGHT RANGE - The range of weights of the capacitors for which the application data are summarized. The units are milliounces.
Source - Direct measurement.

FUNGUS INERT - The treatment of the capacitor against fungus. ECIC Code No. 5.
Test Procedure - MIL-E-5272, Paragraph 4.8.

CORROSION RESISTANCE - The corrosion resistance of the capacitor. ECIC Code No. 6.
Test Procedure - MIL-STD-202, Method 101.

MAXIMUM AMBIENT TEMPERATURE OPERATIVE - The maximum sustained ambient temperature to which a capacitor can be subjected when not in operation, then be energized and operated within all specification limits.
Source - ECIC Test Procedure CC-P1, Paragraph D-2. The maximum temperature for which operating life is 1000 hours.

MINIMUM AMBIENT TEMPERATURE OPERATIVE - The minimum sustained ambient temperature to which a capacitor can be subjected when not in operation, then be energized and operated within all specification limits.
Source - ECIC Test Procedure CC-P1, Paragraph D-2. The minimum temperature for which operating life is 1000 hours.

SUMMARY INFORMATION ON CAPACITORS FOR PUNCHED-CARD FILE

1 October 1953

Card S

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Component	Capacitor	--	2-3	2	1	CC
Type of component		--	4-5	2	20	
Vertical-file breakdown		--	6	1	21	
Index code		--	7-14	8	0	
Manufacturer		--	15-18	4	2	
Specifications		--	19-22	4	22	
Capacitance range		00.1 x 10^N micromicrofarads	23-30	8	--	
Working voltage		0.1 x 10^N volts	31-33	3	--	
Tolerance, plus		00.1 %	34-36	3	--	
Tolerance, minus		00.1 %	37-39	3	--	
Miniaturization range		.01 x 10^N micromicro-$\frac{\text{watt-sec}}{0.001\ \text{in.}^3}$	40-45	6	--	
Weight range		.01 x 10^N milliounces	46-51	6	--	
Fungus inert		--	54	1	5	
Corrosion resistance		--	55	1	6	
Maximum ambient temperature operative		P/N 001. C	56-59	4	--	
Minimum ambient temperature operative		P/N 001. C	60-63	4	--	

Instruction Sheet for Summary Data on Capacitors for Punched-Card File

Card S

(Continued)

Characteristics

MAXIMUM AMBIENT TEMPERATURE NONOPERATIVE - The maximum sustained ambient temperature to which a capacitor may be subjected when not in operation, and from which the capacitor may be returned to its normal operating temperature range and then be operated within all specification limits.

Source - ECIC Test Procedure CC-P1, Paragraph D-2d. The maximum storage temperature for which shelf and operating lives are 1000 hours.

MINIMUM AMBIENT TEMPERATURE NONOPERATIVE - The minimum sustained ambient temperature to which a capacitor may be subjected when not in operation, and from which the capacitor may be returned to its normal operating temperature range and then be operated within all specification limits.

Source - ECIC Test Procedure CC-P1, Paragraph D-2d. The minimum storage temperature for which shelf and operating lives are 1000 hours.

HUMIDITY - This refers to whether or not the capacitor has passed the humidity specifications of MIL-STD-202. ECIC Code No. 7.

Source - MIL-STD-202, Method 103.

ALTITUDE - This refers to whether or not the capacitor has passed the altitude specifications of MIL-STD-202. ECIC Code No. 8.

Source - MIL-STD-202, Method 105.

VIBRATION - This refers to whether or not the capacitor has passed the vibration specifications of MIL-STD-202. ECIC Code No. 9.

Source - MIL-STD-202, Method 201.

SHOCK - This refers to whether or not the capacitor has passed the shock specifications of MIL-STD-202. ECIC Code No. 10.

Source - MIL-STD-202, Method 202.

SERVICE LIFE - The operating life in service that can be expected of a capacitor under normal operating conditions. The units for service life are hours.

Test Procedure - ECIC Test Procedure CC-P1, Paragraph D-2. Life data obtained at 25 C indicate the service life of the capacitor.

QUARTER AND YEAR - The date on which a card is first prepared or completely reviewed and corrected. ECIC Code No. 11.

Source - Supplied by the ECIC.

SUMMARY INFORMATION ON CAPACITORS FOR PUNCHED CARD FILE

Card 8
(Continued)

Characteristics	Insert Known Data Here	Units	Column Number	Number of Columns	Code No.	Value
Maximum ambient temperature nonoperative	______	P/N 001. C	64-67	4	--	______
Minimum ambient temperature nonoperative	______	P/N 001. C	68-71	4	--	______
Humidity	______	--	72	1	7	______
Altitude	______	--	73	1	8	______
Vibration	______	--	74	1	9	______
Shock	______	--	75	1	10	______
Service life	______	$.01 \times 10^N$ hours	76-78	3	--	______
Quarter and year	______	--	79-80	2	11	______

ECIC TENTATIVE TEST PROCEDURES FOR CAPACITORS

PROCEDURE CC-P1

INTRODUCTION

The purpose of these test procedures is to establish uniform methods for obtaining the ECIC data on capacitors.

Wherever possible, the ECIC test procedures are referenced to existing JAN and MIL specifications; however, in many cases, these specifications do not contain provisions for obtaining the life data included in the ECIC files. Where such conditions prevail, the military specifications have been used as a basis and the test has been extended to include such life data. A recommended test procedure has been written in some instances in which no military specification exists for obtaining data under some particular operating condition.

The life tests on capacitors include the effects of environmental and operating conditions on three of the capacitor characteristics; namely, dissipation factor, leakage resistance, and capacitance change (in per cent). Depending on the intended application of the capacitor, any one or more of these characteristics might determine the choice of a particular capacitor.

A. APPLICABILITY

A-1. These test procedures apply to all capacitors suitable for use in electronic equipment.

B. STANDARD TEST CONDITIONS

B-1. Normal Room Ambient Conditions

B-1a. Temperature - 25 C.

B-1b. Barometric Pressure - 30 ± 2 inches of mercury.

B-1c. Humidity - Less than 50 per cent.

B-2. Tolerances - Unless otherwise indicated, the maximum allowable tolerances on test-condition measurements shall be as follows:

B-2a. Temperature - Plus or minus 2 C.

B-2b. Altitude - Plus or minus 5 per cent.

B-2c. Humidity - Plus or minus 5 per cent relative humidity.

B-3. Instruments - The maximum permissible error of measurements during this test shall not exceed 5 per cent or one-quarter of the tolerance, whichever is smaller.

B-4. Number of Samples - Samples for testing purposes shall be chosen as follows:

1. Mica, fixed - JAN-C-5, Paragraph F-3b.

2. Paper, fixed - JAN-C-91, Paragraph F-3a.

3. Paper, fixed and hermetically sealed - JAN-C-25, Paragraph F-19b.

4. Ceramic, fixed - JAN-C-20A, Paragraph F-15b.

5. Ceramic, variable - JAN-C-81, Paragraph F-17b.

6. Air, variable - JAN-C-92, Paragraph F-14c.

7. Dry-electrolytic - JAN-C-62, Paragraph F-3a.

B-5. Test Intervals - All tests must be repeated when a manufacturer makes any change in production methods or materials which may affect the characteristics of the capacitors significantly. In any case, samples based on the production rate are periodically subject to visual and mechanical tests, as well as tests for capacitance, dielectric strength, insulation resistance, Q, and capacitance drift.

B-6. Measurements for Curve-Type Data - A number of points have been suggested at which values for curve-type data are to be measured. In many cases, experience may indicate fewer measurements are sufficient; only enough points need be taken to determine the curve between the indicated test limits.

B-7. Confidence Limits - Estimate 95 per cent confidence limits for the average values by the method given in the following reference: Brownlee, K. A., *Industrial Experimentation*, Chemical Publishing Company, Brooklyn, New York, Third Edition, 1949.

B-8. Methods of Measurement

B-8a. Capacitance and Dissipation Factor - These measurements will be made using a suitable bridge network with a test frequency of one kilocycle or one megacycle per second, according to Paragraph D-10b. A Wagner Ground guard circuit will be attached to the bridge circuit to facilitate virtually error-free measurements of capacitor characteristics in a chamber.

B-8b. Leakage Resistance - This measurement will be made using the galvanometer-voltmeter method with a guard attachment described in the ASTM Designation D 257-49T. The test voltage will be 500 volts or the direct working voltage of the capacitor, whichever is smaller. The test potential will be applied for one minute. A flashover or breakdown occurring during this measurement will constitute a capacitor failure in a life test.

B-8c. Q - Measurement of Q shall be made at a frequency of one megacycle by the use of an instrument involving a source of measured power at that frequency, and a series-resonant circuit with a vacuum-tube voltmeter connected across the capacitive section of the circuit.

C. PRELIMINARY TESTS

C-1. Visual and Mechanical Inspection - Capacitor samples shall be inspected to verify that their workmanship, construction, marking, and physical dimensions are in accordance with the applicable requirements and drawings.

D. TEST PROCEDURES

General

The useful life of a capacitor may be defined as the point at which the dissipation factor, leakage resistance, and capacitance exceed the respective tolerances under which the life tests are conducted. Depending on the type of capacitor and/or its intended application, an excessive variation in any one or all three of the above characteristics may govern the acceptance or rejection of the capacitor. Therefore, in conducting life tests on capacitors, measurements shall be made at each environmental point of the dissipation factor, leakage resistance, and capacitance; in reality, measurements of these quantities throughout the range of environmental conditions will determine three curves indicating the life of the capacitor.

In defining the conditions under which life tests are made, the allowable variations or tolerances on dissipation factor, leakage resistance, and capacitance must be furnished. The allowable tolerance is dependent on the type of capacitor being tested and on its intended application. The ECIC shall furnish the tolerances under which the tests are to be conducted.

D-1. Life Versus Altitude With 95% Confidence Limits (MIL-STD-202, Method 105).

D-1a. Mounting - Capacitors shall be mounted in suitable sample holders by means of soldered connections or by the usual mounting hardware supplied with the capacitor. The capacitors under test shall be so arranged that each is at the same approximate elevation as the other and the temperature of one capacitor is not affected by that of another. At least 12 inches shall separate the capacitors and any wall or enclosure. There shall be no undue draft over the capacitors.

D-1b. Test Method -

D-1b(1). Step I. Initial measurements of the capacitor's characteristics (dissipation factor, leakage resistance, and capacitance) shall be made prior to starting the test. The capacitor samples shall be placed in a suitable altitude chamber in which standard conditions of temperature and humidity can be maintained. The capacitor shall be subjected to an absolute pressure of 11.1 inches of mercury (corresponding to an altitude of 25,000 feet above sea level) and rated working voltage shall be applied. Measurements of the capacitor's characteristics shall be conducted at intervals of 24 hours while the samples are under test. Operation and measurement shall continue until such measurements indicate the capacitors have exceeded the allowable tolerances for all three measures of life (dissipation factor, leakage resistance and capacitance value).

D-1b(2 to 4). Step II to Step IV. Repeat Paragraph D-1b(1) with different capacitor samples, using internal chamber pressures of 3.4, 1.0, and 0.31 inch of mercury (corresponding to altitudes of 50,000, 75,000, and 100,000 feet above sea level), respectively.

D-1b(5 to 8). Step V to Step VIII. Repeat Paragraphs D-1b(1 to 4) with different capacitor samples. Each test, however, shall be conducted with internal temperature and humidity conditions of 50 C (122 F) and 95 to 100 per cent relative humidity. Conduct tests at pressures corresponding to 0, 25,000, 50,000, and 75,000 feet above sea level.

D-1c. Recording of Data - Life in hours shall be recorded as a function of altitude, with failure indicated as the point at which the allowable tolerance is exceeded for dissipation factor, leakage resistance, or change in capacitance.

D-2. Life Versus Temperature With 95% Confidence Limits (MIL-STD-202, Method 102).

D-2a. Mounting - See Paragraph D-1a.

D-2b. Test Method -

D-2b(1). Step I. Prior to starting the test, the capacitor characteristics (dissipation factor, leakage resistance, and capacitance) shall be measured under standard conditions. Then the capacitor samples shall be placed in a suitable test chamber maintained at standard altitude and humidity conditions and shall be subjected to a temperature of -100 C (-148 F) for a period of 6 hours. At the end of this period and at the same temperature, the capacitors shall be operated under rated conditions and their above characteristics measured at 12-hour intervals. The cycle of operation and measurement shall continue until the total elapsed operating time equals 1000 hours, or until measurements indicate the capacitors have exceeded their allowable tolerances.

D-2b(2 to 10). Step II to Step X. Repeat Paragraph D-2b(1) with different capacitor samples using temperatures of -65 C (-85 F), -35 C (-31 F), 0 C (32 F), 25 C (77 F), 50 C (122 F), 100 C (212 F), 150 C (302 F), 200 C (392 F), and 250 C (482 F), respectively.

D-2c. Recording of Data - Life in hours shall be recorded as a function of temperature, with failure indicated as the point at which the allowable tolerance is exceeded for dissipation factor, leakage resistance, or change in capacitance.

D-2d. Operative and Nonoperative Conditions - Operative life data shall be obtained from the test described above. Nonoperative life data shall be obtained under much the same conditions; however, before operation of the capacitor, its temperature must be returned to its standard value. Data obtained at 25 C indicate the shelf life at the capacitor.

D-3. Life Versus Frequency With 95% Confidence Limits

D-3a. Mounting - See Paragraph D-1a.

D-3b. Test Method -

D-3b(1). Step I. The capacitor samples shall be operated at rated working voltage under standard ambient conditions (see Paragraph B-1). The voltage shall be supplied by a signal generator having a 60-cycle-per-second sinusoidal output. At the start of the test and at periodic intervals thereafter, the characteristics (dissipation factor, leakage resistance, and capacitance) of the capacitors shall be measured. The test shall continue under these conditions until measurements indicate the capacitors have exceeded their allowable tolerances.

D-3b(2 to 5). Step II to Step V. Repeat Paragraph D-3b(1) with different capacitor samples using test frequencies of 1000, 100,000 1,000,000, and 10,000,000 cycles per second, respectively.

D-3c. <u>Recording of Data</u> - Life in hours shall be recorded as a function of frequency, with failure indicated as the point at which the allowable tolerance is exceeded for dissipation factor, leakage resistance, or change in capacitance.

D-4. <u>Life Versus % Rated Working Voltage With 95% Confidence Limits</u>

D-4a. <u>Mounting</u> - See Paragraph D-1a.

D-4b. <u>Test Method</u> -

D-4b(1). Step I. Rated working voltage shall be impressed across the capacitor terminals; the test shall be carried out under standard test conditions (see Paragraph B-1). Measurements of the capacitor characteristics (dissipation factor, leakage resistance, and capacitance) shall be made at the start of the test and at periodic intervals thereafter. The test shall continue until measurements indicate the capacitor no longer meets the allowable tolerances.

D-4b(2 to 5). Step II to Step V. Repeat Paragraph D-4b(1) with different capacitor samples using rated working percentages of 25, 50, 150, and 200, respectively.

D-4c. <u>Recording of Data</u> - Life in hours shall be recorded as a function of working voltage, with failure indicated as the point at which the allowable tolerance is exceeded for dissipation factor, leakage resistance, or change in capacitance.

D-5. <u>Life Versus Vibration With 95% Confidence Limits</u> (MIL-STD-202, Method 201).

D-5a. <u>Mounting</u> - See Paragraph D-1a.

D-5b. <u>Test Method</u> -

D-5b(1). Step I. The capacitor samples shall be mounted in the position most likely to produce the severest results from vibration. Prior to the start of the test, the characteristics (dissipation factor, leakage resistance, and capacitance) shall be measured under standard conditions. Then the capacitors shall be subjected to a simple harmonic motion having an amplitude of 0.01 inch; the frequency of vibration shall be varied uniformly between the approximate limits of 10 and 55 cycles per second. The entire frequency range from 10 to 55 cycles per second and return shall be traversed in approximately one minute. The entire test shall be performed under standard test cpnditions (see Paragraph B-1) with rated working voltage applied to the capacitors. Testing shall continue with periodic measurements of the capacitor characteristics until such measurements indicate the capacitors no longer meet the allowable tolerances.

D-5b (2 to 4). Step II to Step IV. Repeat Paragraph D-5b(1) with different capacitor samples using vibration amplitudes of 0.02, 0.04, and 0.06 inch, respectively.

D-5c. Recording of Data - Life in hours shall be recorded as a function of vibration, with failure indicated as the point at which the allowable tolerance is exceeded for dissipation factor, leakage resistance, or change in capacitance.

D-6. Life Versus Shock With 95% Confidence Limits (MIL-STD-202, Method 202).

D-6a. Mounting - See Paragraph D-1a.

D-6b. Test Method -

D-6b(1). Step I. Prior to the start of the test, rated working voltage shall be applied to the capacitors under standard test conditions and their characteristics (dissipation factor, leakage resistance, and capacitance) shall be measured. Then the capacitor samples shall be mounted on a suitable shock-testing apparatus and operated under standard conditions while being subjected to repeated shocks of 2 G's intensity. Measurements of the capacitor characteristics shall be made at periodic intervals throughout the test. The test shall continue until measurements indicate the capacitors no longer meet the allowable tolerances, or until inspection reveals physical damage to the sample.

D-6b(2 to 6). Step II to Step VI. Repeat Paragraph D-6b(1) with different capacitor samples using shock intensities of 5, 10, 20, 40, and 70 G's, respectively.

D-6c. Recording of Data - Life in hours shall be recorded as a function of shock, with failure indicated as the point at which the allowable tolerance is exceeded for dissipation factor, leakage resistance, or change in capacitance.

D-7. Life Versus Pulse Type With 95% Confidence Limits

D-7a. Mounting - See Paragraph D-1a.

D-7b. Test Method -

D-7b(1). Step I. Initial measurements of the capacitor characteristics (dissipation factor, leakage resistance, and capacitance) shall be made under standard test conditions. The capacitor samples shall then be operated under rated working voltage, supplied by a suitable signal generator having a full-sine-wave output. Operation of the samples under these conditions shall continue, with periodic measurements of the capacitor characteristics, until indications show the capacitors no longer meet the allowable tolerances.

D-7b(2 to 9). Step II to Step IX. Repeat Paragraph D-7b(1) with different capacitor samples using signal generators capable of the following output wave types, respectively:

1. Rectangular-wave output

2. Half-sine-wave output

3. Triangular-wave output

4. Clipped-sawtooth-wave output

5. Symmetrical-trapezoid-wave output

6. Damped-exponential-wave output

7. Fractional-sine-wave output

8. Asymmetrical-wave output

D-7c. Recording of Data - Life in hours shall be recorded as a function of pulse type, with failure indicated as the point at which the allowable tolerance is exceeded for dissipation factor, leakage resistance, or change in capacitance.

D-8. Voltage Peak Versus Temperature

D-8a. Mounting - See Paragraph D-1a.

D-8b. Test Method -

D-8b(1). Step I. The capacitors shall be mounted in a suitable chamber, in which standard conditions of altitude and humidity can be maintained. The test shall be conducted under standard ambient temperature conditions. The initial sinusoidal pulse of two times the rated working voltage shall be applied to the samples five times. If breakdown of the capacitor fails to occur, the pulse voltage shall be increased by 5 per cent of the initial value and again applied five times across the terminals of the capacitors. The test shall continue with increasing values of pulse voltage until breakdown occurs. The voltage peak shall be the value of voltage immediately below that which causes breakdown.

D-8b(2 to 4). Step II to Step IV. Repeat Paragraph D-8b(1) with different capacitor samples using ambient temperature conditions of -40 C (-40 F), 75 C (167 F), and 150 C (302 F), respectively.

D-9. Absorption

D-9a. Mounting - See Paragraph D-1a.

D-9b. Test Method - The test for absorption shall be conducted under standard test conditions (see Paragraph B-1). The capacitors under test shall be charged to their rated working voltages for a period of one minute. The terminals of the capacitors shall be shorted for one second and then

the capacitors shall be insulated for 30 seconds. The voltage across the terminals of the capacitors shall be read on a vacuum-tube voltmeter; the measurement of voltage shall be repeated at 30-second intervals for a total of five times. The product of the sum of the voltages and the measured capacitance of the capacitor shall be determined and expressed in micromicrocoulombs.

D-10. Dissipation Factor

D-10a. Mounting - See Paragraph D-1a.

D-10b. Test Method - The dissipation factor of a capacitor can be measured on a Schering bridge or an equivalent instrument. The dissipation factors of capacitors whose value is 400 $\mu\mu f$ or greater shall be measured at 1000 cycles per second; capacitors whose dissipation value is less than 400 $\mu\mu f$ shall have their dissipation factors measured at one megacycle per second.

20 TYPE OF COMPONENT

Column 4	Code	Class & Adjustability
	1	Class I Fixed
	2	Class II Fixed
	3	Class III Fixed
	4	Class IV Fixed
	5	Class I Variable
	6	Class II Variable

Column 5		Dielectric Materials			
		Class I	Class II	Class III	Class IV
	0	Vacuum	Bakelite	Castor oil	Dry electrolyte
	1	Air	Hard rubber	Chlorinated diphenyl	Wet electrolyte
	2	Argon	Mycanite	Chlorinated naphthalene	
	3	Helium	Steatite	Cellophane	
	4	Neon	Glass, plate	Mineral oil	
	5	Hydrogen	Glass, Pyrex	Cellulose acetate	
	6	Nitrogen	Mica	Paraffin	
	7	Carbon dioxide	Mycalex	Paper	
	8		Porcelain	Polystyrene	
	9		Quartz	Paper and Halowax	
	A		Titanium dioxide	Paper and castor oil	
	B		TiO_2 + ceramics		

Definitions for "Type of Component" Capacitor Code

CLASS 1 — Capacitors using air, gas, or vacuum as a dielectric.

CLASS 2 — Capacitors having a hard dielectric, such as mica and ceramics.

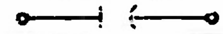
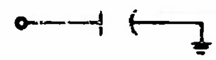
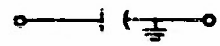
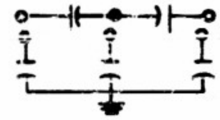
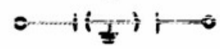
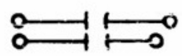
CLASS 3 — Capacitors having soft dielectrics, such as paper, oil, wax, and films.

CLASS 4 — Capacitors using a physical-chemical reaction as the dielectric.

21 VERTICAL-FILE BREAKDOWN

Column 6	Code	Voltage	Inch Air Gap
	0	Multiple Section	
	1	0-75	
	2	75^{+}-300	
	3	300^{+}-500	
	4	500^{+}-1000	.030
	5	1000^{+}-3000	$.030^{+}$-.070
	6	3000^{+}-5000	$.070^{+}$-.144
	7	5000^{+}-10,000	$.144^{+}$-.375
	8	$10,000^{+}$-14,000	$.375^{+}$-.600
	9	$14,000^{+}$	$.600^{+}$

24 CIRCUIT

Column 30	Code	Circuit
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	

25 VOLTAGE COEFFICIENT OF CAPACITANCE

Columns 31-32	Code	
		In most cases this characteristic is insignificant, but this characteristic will apply in the case of ceramic-dielectric capacitors. At present there are not enough data to supply a well-defined code for this. Leave columns blank until a code is available.

26 TEMPERATURE COEFFICIENT OF CAPACITANCE

Columns 33-34	Code	Parts per million per degree C		Code	Parts per million per degree C		Code	Parts per million per degree C	
		Nominal	Symmetric		Nominal	Symmetric		Nominal	Symmetric
	AH	+100	±60	HF	-30	±15	RH	-220	±60
	AJ	+100	±120	HG	-30	±30	RJ	-220	±120
	AK	+100	±250	HH	-30	±60	RK	-220	±250
	BF	+30	±15	HJ	-30	±120	SH	-330	±60
	BG	+30	±30	HK	-30	±250	SJ	-330	±120
	BH	+30	±60	LG	-80	±30	SK	-330	±250
	BJ	+30	±120	LH	-80	±60	SL	-330	±500
	BK	+30	±250	LJ	-80	±120	TH	-470	±60
	CF	Zero	±15	LK	-80	±250	TJ	-470	±120
	CG	Zero	±30	PG	-150	±30	TK	-470	±250
	CH	Zero	±60	PH	-150	±60	UJ	-750	±120
	CJ	Zero	±120	PJ	-150	±120	UK	-750	±250
	CK	Zero	±250	PK	-150	±250			

JAN - C - 20A contains the tables and curves that are to be used with this code. See paragraph H-7 and Figures 11-20.

DATA-COLLECTION SHEETS

FOR CAPACITORS

Instructions for Data-Collection Sheets for Capacitors

MANUFACTURER - The name and location of the firm which manufactures the capacitor.

MANUFACTURER'S TYPE NUMBER - The number assigned by the manufacturer to identify capacitors as to method of construction, materials used, etc.

MANUFACTURER'S PART NUMBER - The number assigned by the manufacturer to identify a particular capacitor.

LIST PRICE PER CAPACITOR - The current list price per individual capacitor.

TYPE OF CAPACITOR - A check list to indicate the degree of adjustability of the capacitor and the class of dielectric used in its manufacture. The name or description of the dielectric material is also requested.

NUMBER OF SECTIONS - The total number of individual capacitors contained in the unit described.

CAPACITANCE - The nominal capacitance, in micromicrofarads.

D-C WORKING VOLTAGE - The nominal d-c working-voltage rating of the capacitor.

SHAPE - A check list to indicate the shape of the capacitor. The shape shall give the least volume completely enveloping the capacitor. Leads and terminals easily bent need not be considered as part of the shape; mounting brackets which are an integral part of the capacitor must be included in the shape.

DIMENSIONS "A", "B", AND "C" - The dimensions, in inches, corresponding to the letters on shape indicated above.

WEIGHT - The weight of the capacitor, in ounces.

NUMBER OF TERMINALS - The exact number of terminals on the capacitor.

TERMINAL TYPE - The type of terminal used on the capacitor.

TERMINAL ARRANGEMENT - An indication of the physical location of the terminals on the capacitor.

MOUNTING METHODS - An indication as to how the capacitor shall be mounted on any assembly.

CASE MATERIAL - The name or a description of the base material used to cover the capacitor.

PROTECTIVE COVERING - The name or a description of the material used to protect the capacitor against its external environment.

SPECIFICATIONS - A listing of the specifications (JAN, MIL, etc.) which the capacitor has passed in a manner acceptable to the issuing agency.

FUNGUS INERT - An indication as to whether the capacitor has met the requirements of MIL-E-5272 concerning protection against fungus growth.

CORROSION RESISTANT - An indication as to whether the capacitor has met the requirements of MIL-STD-202, Method 101, concerning protection against corrosion.

HUMIDITY - An indication as to whether the capacitor has met the humidity requirements of MIL-STD-202, Method 103.

ALTITUDE - An indication as to whether the capacitor has met the altitude requirements of MIL-STD-202, Method 105.

VIBRATION - An indication as to whether the capacitor has met the vibration requirements of MIL-STD-202, Method 201.

SHOCK - An indication as to whether the capacitor has met the shock requirements of MIL-STD-202, Method 202.

DATA-COLLECTION SHEET FOR CAPACITORS*

Manufacturer of Capacitor ____________________

Manufacturer's Type Number ____________________

Manufacturer's Part Number ____________________ List Price per Capacitor ____________________

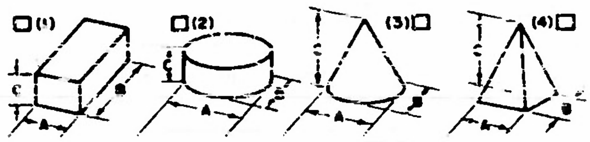
Type of Capacitor (check appropriate items)

Fixed	Class I	Name of Dielectric Material
Variable	Class II	____________________
	Class III	____________________
	Class IV	

Number of Sections per Unit ____________* D-C Working Voltage ____________ volts

Capacitance ____________ uuf

Shape ☐ (1) ☐ (2) (3) ☐ (4) ☐



Dimension A ________ in. Dimension B ________ in. Dimension C ________ in.

Weight ____________ oz

Number of Terminals ____________

Terminal Type: Flexible-Wire Lead Solder Lug Screw and Nut

Other ____________________

Terminal Arrangement: Top Bottom End Sides

Other ____________________

Mounting Method: Leads Solder Lug Clamps Twist Lug

Other ____________________

Case Material ____________________

Protective Covering (finish or plating) ____________________

Specifications ____________________

Has the Capacitor Passed the Test Requirements of the Specification Indicated Below?

Fungus Inert:	MIL-E-5272	Passed		Not Passed
Corrosion Resistant:	MIL-STD-202	Passed	A B	Not Passed
Humidity:	MIL-STD-202	Passed	A B	Not Passed
Altitude:	MIL-STD-202	Passed		Not Passed
Vibration:	MIL-STD-202	Passed	A B	Not Passed
Shock:	MIL-STD-202	Passed		Not Passed

*Use these data-collection sheets for electrical data on single-section capacitors or for Section No. 1 of a multisection capacitor. Sections of a multisection capacitor are numbered according to the working voltage, Section No. 1 being assigned to the lowest voltage section.

Instructions for Data-Collection Sheets for Capacitors

MAXIMUM AMBIENT TEMPERATURE OPERATIVE - The maximum sustained ambient temperature to which a capacitor may be subjected when not in operation, then be energized and operated within all specification limits for a period of 1000 hours.

MINIMUM AMBIENT TEMPERATURE OPERATIVE - The minimum sustained ambient temperature to which a capacitor may be subjected when not in operation, then be energized and operated within all specification limits for a period of 1000 hours.

MAXIMUM AMBIENT TEMPERATURE NONOPERATIVE - The maximum sustained ambient temperature to which a capacitor may be subjected when not in operation, and from which the capacitor may be returned to its normal operating temperature range, and then be operated within all specification limits for 1000 hours.

MINIMUM AMBIENT TEMPERATURE NONOPERATIVE - The minimum sustained ambient temperature to which a capacitor may be subjected when not in operation, and from which the capacitor may be returned to its normal operating temperature range, and then be operated within all specification limits for 1000 hours.

TOLERANCE, PLUS OR MINUS - The permissible plus or minus deviation from the nominal value of capacitance. The units are per cent.

FREQUENCY RANGE OF APPLICATION - The frequency range over which the capacitor may be operated and remain within its nominal ratings.

PEAK VOLTAGE - The maximum instantaneous voltage which can be safely impressed across the terminals of the capacitor.

A-C VOLTAGE - The nominal a-c voltage which can be safely and continuously impressed across the terminals of the capacitor under normal operating conditions.

VOLTAGE COEFFICIENT OF CAPACITANCE - The parts per million change in capacitance per volt change in voltage across the terminals of the capacitor.

TEMPERATURE COEFFICIENT OF CAPACITANCE - The parts per million change in capacitance per degree (centigrade) change in temperature.

ABSORPTION - The amount of charge retained in the capacitor after the d-c working voltage has been applied for a fixed period of time and the capacitor then shorted for a fixed period of time.

DISSIPATION FACTOR - The ratio of the energy lost through leakage plus i^2R losses to the energy retained in the capacitor.

CIRCUIT INDUCTANCE - The self-inductance of the capacitor.

RESONANT FREQUENCY - The frequency at which the impedance between the terminals reaches a minimum value (or becomes resistive).

CORONA VOLTAGE - The voltage across the terminals of the capacitor at which ionization begins to occur in the dielectric.

INSULATION RESISTANCE - The resistance measured between the shorted terminals of the capacitor and the case.

VOLTAGE INSULATION - The maximum d-c voltage which can be impressed across the shorted terminals of the capacitor and the case before damage occurs.

SERVICE LIFE - The operating life in service that can be expected of a capacitor under normal operating conditions.

SHELF LIFE - The life in storage under normal conditions, from which the capacitor may be placed in service and operate normally in all respects.

CIRCUIT - A schematic representation of the physical relationship between the capacitor elements and its terminals.

DATA COLLECTION SHEET FOR CAPACITORS

List Temperatures Below:

Maximum Ambient Temperature Operative ____________ C

Minimum Ambient Temperature Operative ____________ C

Maximum Ambient Temperature Nonoperative ____________ C

Minimum Ambient Temperature Nonoperative ____________ C

Tolerance: Plus ________ % Minus ________ % Frequency Range of Application ________

Peak Voltage ____________ volts A-C Voltage ____________ volts

Voltage Coefficient of Capacitance ________________ Temperature Coefficient of Capacitance ____________

Absorption ____________ micromicrocoulombs Dissipation Factor ____________ %

Circuit Inductance ____________ microhenries Resonant Frequency ____________

Corona Voltage ______________ volts Insulation Resistance ____________

Voltage Insulation ____________ volts Service Life ______________ hours

Shelf Life ______________ years

Circuit (schematic diagram of capacitor circuit)

DATA-COLLECTION SHEET FOR CAPACITORS

(For supplementary multisection-capacitor data)*

	Section No. 2	Section No. 3	Section No. 4
Capacitance			
D-C Working Voltage, volts			
Peak Voltage, volts			
Absorption, micromicrocoulombs			
Dissipation Factor, %			
A-C Voltage, volts			
Voltage Coefficient of Capacitance			
Temperature Coefficient of Capacitance			
Circuit Inductance, microhenries			
Frequency Range of Application, cycles/sec			
Resonant Frequency,			

*Use this data collection sheet for the inclusion of electrical data on the remaining sections of a multisection capacitor. Data pertaining to the characteristics listed above should be denoted as "same" if such data are identical with those already given for Section No. 1. Additional characteristics and data may be added if required.

LIFE-DATA-COLLECTION SHEETS FOR CAPACITORS

Manufacturer's Type and Part Number ______________

Number of Samples Used per Test ______________ *

Life-Test Tolerances

Dissipation Factor ________ %
Leakage Resistance ________ megohms
Capacitance Change ________ %

Life Versus Altitude With 95% Confidence Limits (C.L.) (ECIC Test Procedure CC-P1, Paragraph D-1)

Life Values and Confidence Limits, hours

Altitude, feet	Dissipation Factor		Leakage Resistance		Capacitance Change	
	Life	C.L.	Life	C.L.	Life	C.L.
(Data obtained under standard test conditions)						
25,000	___	___	___	___	___	___
50,000	___	___	___	___	___	___
75,000	___	___	___	___	___	___
100,000	___	___	___	___	___	___
(Data obtained under test conditions of 50 C and 95 to 100 per cent relative humidity)						
25,000	___	___	___	___	___	___
50,000	___	___	___	___	___	___
75,000	___	___	___	___	___	___
100,000	___	___	___	___	___	___

Life Versus Temperature With 95% Confidence Limits (ECIC Test Procedure CC-P1, Paragraph D-2)

Life Values and Confidence Limits, hours

Temperature, C	Dissipation Factor		Leakage Resistance		Capacitance Change	
	Life	C.L.	Life	C.L.	Life	C.L.
-100	___	___	___	___	___	___
- 65	___	___	___	___	___	___
- 35	___	___	___	___	___	___
0	___	___	___	___	___	___
25	___	___	___	___	___	___
50	___	___	___	___	___	___
100	___	___	___	___	___	___
150	___	___	___	___	___	___
200	___	___	___	___	___	___
250	___	___	___	___	___	___

* The number of samples used in each test shall be governed by the applicable specification; five samples shall be tested where the number of samples is not specified. The life values recorded are the average values for the samples tested. Confidence limits are calculated from tests on the specified number of samples; if confidence limits are not calculated, list life data from each individual sample on additional pages.

LIFE-DATA-COLLECTION SHEETS FOR CAPACITORS

Life Versus Frequency With 95% Confidence Limits (ECIC Test Procedure CC-P1, Paragraph D-3)

Life Values and Confidence Limits, hours

Frequency, cycles/sec	Dissipation Factor		Leakage Resistance		Capacitance Change	
	Life	C. L.	Life	C. L.	Life	C. L.
60						
1000						
100,000						
1,000,000						
10,000,000						

Life Versus % Rated Working Voltage With 95% Confidence Limits (ECIC Test Procedure CC-P1, Paragraph D-4)

Life Values and Confidence Limits, hours

% Rated Working Voltage	Dissipation Factor		Leakage Resistance		Capacitance Change	
	Life	C. L.	Life	C. L.	Life	C. L.
25						
50						
100						
150						
200						

Life Versus Vibration With 95% Confidence Limits (ECIC Test Procedure CC-P1)

Life Values and Confidence Limits, hours

Vibration Amplitude, inch	Dissipation Factor		Leakage Resistance		Capacitance Change	
	Life	C. L.	Life	C. L.	Life	C. L.
0.01						
0.02						
0.04						
0.06						

LIFE-DATA-COLLECTION SHEETS FOR CAPACITORS

Life Versus Shock With 95% Confidence Limits

Life Values and Confidence Limits, hours

Shock, G's	Dissipation Factor		Leakage Resistance		Capacitance Change	
	Life	C. L.	Life	C. L.	Life	C. L.
2						
5						
10						
20						
40						
70						

Life Versus Pulse Type With 95% Confidence Limits

Life Values and Confidence Limits, hours

Pulse Type	Dissipation Factor		Leakage Resistance		Capacitance Change	
	Life	C. L.	Life	C. L.	Life	C. L.
Full sine						
Rectangular						
Half sine						
Triangular						
Clipped sawtooth						
Symmetrical trapezoid						
Damped exponential						
Fractional sine						
Asymmetrical trapezoid						

Voltage Peak Versus Temperature

Temperature, C	Voltage Peak, volts
-40	
25	
75	
150	

Answering Questions

What Type of Questions Could the ECIC Answer?

The system is designed so that, once all the pertinent data on a given electronic-component group have been inserted into the files, any engineering question of fact, involving design or performance data, could be answered. The scope of the possible answers would depend upon the extent of the input data on the component at the time.

The following list suggests the variety of questions potentially answerable by an ECIC system in full-scale operation:

(1) Are there any 500-volt d-c 10-μf capacitors available that will operate satisfactorily for 100 hours at an ambient temperature of 200 C? If so, who makes them?

(2) Who manufacturers an hermetically glass-sealed resistor, 40,000 ohms, 1 watt, "one per cent accuracy"?

(3) Who makes the lightest weight 1/10-hp, 10,500-rpm, 400-cycle induction motor available? What is its weight?

(4) What is the smallest available dry battery that will deliver 9.5 amperes continuously for 1-1/2 hours at 0 F with a working voltage of 2.5 volts?

(5) List the available thermal switches meeting the following requirements:

Type of operation	snap action
Actuating temperature.	75 F
Release temperature	73 F
Voltage rating	200
Frequency, cycles	400
Current rating	2 amperes

Sensitive element that will not be damaged by storage at temperatures ranging from -40 to 120 F.

(6) List the United States transistor manufacturers by states.

How Would the Center Answer Such Questions?

To answer a question, the procedure, in general, would be as follows:

(1) Screening of Questions. An ECIC engineer would ascertain that the question was answerable; i.e., it was a question of fact, and not ambiguous or a matter of opinion.

(2) Searching. He would then determine which file to search, which machine to use, and the simplest way to prepare the machine for the searching job. Often this would require only the punching of a master selector card for machine-matching by the collator. For a more complex and detailed question, a 5-minute job of panel wiring might be necessary (collator or electronic statistical machine). Each machine-panel "hook-up" that was to be used frequently in the searching operation could be wired into a separate panel. These separate, permanently wired panels could be used to facilitate machine-job changes by reducing the amount of machine-panel wiring necessary.

A technician would take over the procedure of feeding the cards into the selecting machine (sorter, collator, or electronic statistical machine), which would select those cards pertinent to the answer desired and reject the others.

(3) Tabulating and Tape Punching. Once the cards were selected, the information on them could be tabulated automatically on a Cardatype or on a standard alphanumeric tabulator. The Cardatype can be wired so that it would simultaneously punch a teletypewriter transmittal tape with the same information as that tabulated.

(4) Verifying Accuracy of Answers. When the data have been tabulated, an engineer would check them for completeness and accuracy, and prepare any explanatory remarks he felt were necessary. The answer to the inquirer's question would then be ready for transmittal.

(5) Transmittal of Answers. The data could be sent to the inquirer by means of the tabulated lists or on the punched tape. If the questioner were acquainted with the ECIC he would have a copy of the simple codes involved in all probability. In that case, decoding of the punched-card data by the ECIC would not be necessary; but even decoding would delay the answer only slightly. Most questions could be answered within 8 working hours after their receipt by the ECIC.

Part VII of Phase Report No. 1 (page 121) illustrates the various steps to be taken in answering questions like those mentioned above.

Punch Cards and Machines for the ECIC

A number of commercially available methods for handling technical information were considered for use in the ECIC. These included hand-sorted punched cards, machine-sorted punched cards, microfilm, micro-cards, magnetic-tape devices, and various combinations of these.

The method finally selected as most nearly meeting the immediate requirements of an ECIC system was that employing machine-sorted punched cards. The reasons underlying this selection were:

(1) Information could be added to or removed from the files easily.

(2) The equipment was commercially available and could be rented as needed.

(3) Machine searching permits rapid selection of desired information from a large file.

(4) Automatic machines for reproducing card punching and for printing data directly from cards could speed the processing of information.

(5) Anticipated growth would not result in an unwieldy system.

This section describes briefly the machine-sorted punched card and the various machines recommended for use by an ECIC.

Description of the Punched Card Used in the ECIC System

The machine-sorted punched card (IBM) has 80 vertical columns, each divided into twelve punching positions. Using only standard punches, there are 47 different letters, numbers, and special characters available, any one of which may be punched into a card column.

Functionally, there is only one basic card design. However, various card-color combinations and special printing facilitate the identification and handling of card decks by operators.

Machines for ECIC Use

Card Punch. The printing card punch may be used to prepare punched cards for the files of ECIC. Punching is controlled by a typewriter-like keyboard. The printing punch, in addition to punching holes, also prints, at the top of the card column, the character represented by the

holes punched in that column. The machine has a program-control unit that permits automatic duplication and automatic skipping of cards or parts of cards. The duplication and skipping program desired may be punched on a standard card whose punching pattern controls the automatic functions of the machine.

Card Verifier. The card verifier may be used to check the punching of cards prepared for the ECIC files. Verification is accomplished by a key operation similar to card punching. Depressing a verifier key compares the hole or holes already punched in the corresponding card column with the pattern desired. A discrepancy causes the machine to stop.

Card Collator. The card collator may be used for sequence checking, card selection, merging, matching, and merging with selection. It has two card feeds and four collecting pockets.

Machine functions are determined by wiring on a control panel. Card comparing can be done on sixteen columns for both numerical and alphabetical information.

Each card feed has a speed of 240 cards per minute. When both feeds operate every card cycle, 480 cards per minute pass through the machine.

In the ECIC, the card collator would be used for checking the sequence of electronic-component index codes, verifying the punching of identical columns, selection of particular component cards, matching identical decks of file cards, and a variety of other functions. In selecting, for instance, a question card may be prepared that contains values sought as an answer. The collator can select from a deck of ECIC cards all of those that match the question card.

Electronic Statistical Machine. The electronic statistical machine has four main functions, i.e., sorting, selecting, counting, and printing tables of information. It has one card feed and thirteen collecting pockets.

Sorting is the operation by which the cards are arranged in numerical or alphabetical sequence.

Selecting is similar to sorting, except that only cards with specified punched patterns are removed from the deck. The selected cards fall into one or more pockets, as desired, and the balance fall into another pocket, usually the reject pocket. Cards can be selected on the basis of information in several columns. For instance, it may be desired to select all cards having the Number 628A in Columns 3 to 6. This can be done very simply in one pass through the machine.

The number of cards in any classification can be determined by the counters. While the count is being made, the cards can be sorted into an entirely different group of classifications, or can be retained in the same order by being directed into one pocket.

The card counts can be printed automatically on a report form. By proper grouping of the cards, a table of data can be printed directly.

Machine functions are determined by a wiring panel and selector switches. Cards feed at the rate of 450 per minute.

In the ECIC, the electronic statistical machine can be used to sort numerical and alphabetical information, check sequence, select component cards in answer to inquiries, and count classifications for printing data.

Cardatype. The Cardatype may be used to prepare a typewritten document semiautomatically. It is an electric typewriter controlled by a program tape and a plugboard control panel. The Cardatype can by shifted quickly from one job to a different one merely by changing program tapes. Information for typing can be fed to the machine from a punched card, a typewriter keyboard, or an auxiliary keyboard.

In addition to printing data from punched cards, the Cardatype can be made to stop where desired, so that information from a typewriter keyboard can be inserted by hand typing. There is also an auxiliary keyboard in which numerical information can be prepunched by hand and inserted automatically upon "orders" from the program tape.

Another feature of the Cardatype, the transmittal-tape punch, may be used to prepare a teletype tape from punched cards. The tape may be punched at the same time the information is being typed.

The maximum speed of the Cardatype is 10 characters per second. The average typing rate is somewhat less than this, depending upon the time consumed by machine operations, such as carriage return, card eject, etc., but it is faster than expert manual typing.

A tabulator and card-to-tape punch could replace the Cardatype in a large-scale operation. The Cardatype could be used by ECIC in a small-scale operation or for miscellaneous jobs in a large information center.

Automatic Reproducing Punch. The functions of the automatic reproducing punch in the ECIC fall into three main groups, viz., reproducing, gang punching, and comparing. Duplicate decks of cards can be prepared automatically by the reproducer. Gang punching can be used to prepare a large number of identical cards. This operation can be used when it is desired to add the same information to a number of cards.

The reproducer can be used to compare two decks of cards that are thought to be identical. A mark-sensing attachment will permit the reproducer to read pencil marks on the card and punch this information into the proper columns.

The Tabulating Machine. The tabulating machine can be used to prepare listings of data from the ECIC cards. These listings then can be returned to the source of data for checking. The tabulator also can list answer cards selected from the ECIC files. It also can count and accumulate totals. The tabulator could be used in place of the Cardatype in a large information center where its higher speed would be essential. Some tabulators can print 150 lines per minute (up to 120 characters per line).

The Card-Controlled Tape Punch. The card-controlled tape punch can be used to prepare a teletype tape from the punched cards. The teletype tape can be used then to transmit information between the central ECIC and any branches that might be set up, or it can be used to transmit directly to the questioner information from selected cards that answers his question.

The punch, collator, Cardatype, and electronic statistical machine can perform the basic operations required by the ECIC and are all the machines required for a small-scale operation. A larger center could make efficient use of the tabulator, reproducer, verifier, and card-to-tape punch.

The foregoing paragraphs contain only brief descriptions of the IBM machines recommended for use in an ECIC. More detailed descriptions of the IBM card, printing card punch, Cardatype, collator, and electronic statistical machine, as applied to an ECIC system, may be found in Part II of Phase Report No. 1. Complete information on all the machines mentioned in this section can be found in the operating manuals furnished by the manufacturer.

Organization and Personnel

This section discusses briefly the principal elements of a suggested organizational setup for a unit of ECIC operation and the personnel requirements for such a unit. The word "unit" is used here to mean a group of individuals (and equipment) organized to perform all the "line" operations of the proposed center on a typical, but limited, scale — for instance, service on a limited number of components or on a fixed maximum amount of ECIC business. The number of such units that would be required depends, of course, upon the level of activity. The supervision of a group of these units, the management and administration of the ECIC as a whole, and any research and development activities, are not included in the discussion.

Figure 6 is a suggested organizational chart for an ECIC unit showing the various occupations represented and the lines of responsibility. The job titles were selected to correspond with those used in the operational analysis of costs presented later, in Table 5.

Different job titles, especially for the engineering jobs, might be equally appropriate. The job descriptions are as follows.

Engineers

(1) Job Title - Coordinating Engineer (Reply Editor)

Job Description - Supervises one unit of ECIC operation and checks all input data and outgoing information from that unit

Requirements - Degree in Electrical Engineering or the equivalent. Comprehensive understanding of the properties and uses of electronic components. Thorough knowledge of all ECIC operations, equipment, and personnel. Should have six months' ECIC experience at less responsibility.

Salary = $6000 to $7500 per year (1953)

(2) Job Title - Search Specialist

Job Description - Determines and specifies methods of using the machines for each data search. Supervises operation of all machines except card punch and verifier. Schedules all searching work.

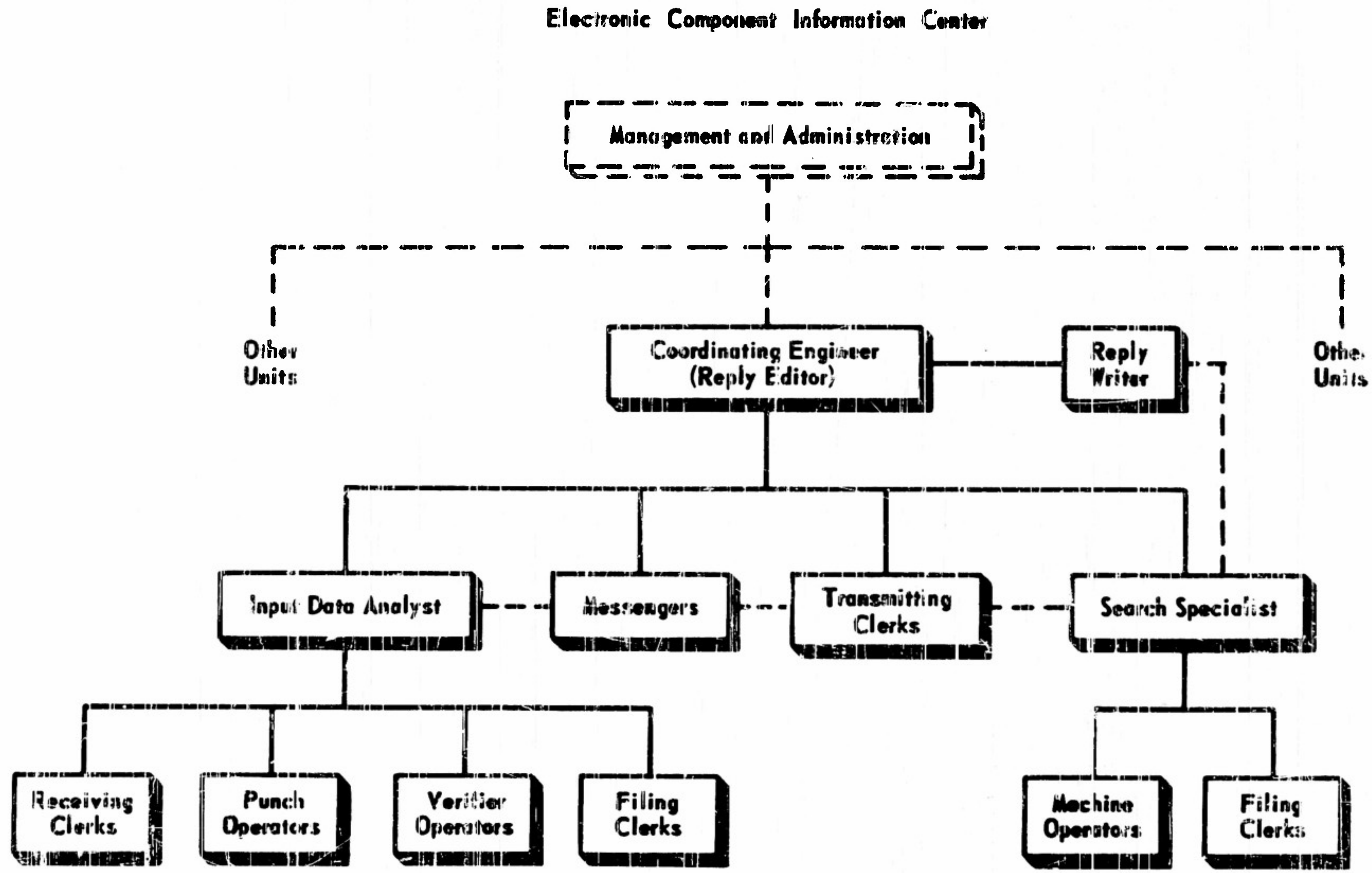


FIGURE 6. SUGGESTED ORGANIZATION OF A TYPICAL ECIC UNIT

Requirements - Degree in Electrical Engineering or the equivalent. Thorough knowledge of the ECIC searching techniques and searching-machine operation. Should have six months' ECIC experience at less responsibility covering all phases of ECIC work.

Salary - \$5000 to \$6500 per year (1953)

(3) Job Title - Data Analyst

Job Description - Analyzes incoming information or questions for ECIC processing. Translates incoming data into ECIC codes and forms. Supervises and schedules punching and verifying of cards and all card filing.

Requirements - Degree in Electrical Engineering or the equivalent. Comprehensive understanding of the properties of electronic components. Familiarity with ECIC data collection, operating system, and coding. Should have six months' ECIC experience.

Approximate Salary - \$4200 to \$5000 per year (1953)

Machine Operators (Technicians)

(1) Job Title - Searching Machine Operator (collator, electronic statistical machine, etc.)

Job Description - Follows search specialist's instruction in wiring panel boards and operating machines to find cards that contain the desired information.

Requirements - High school diploma. One or two weeks' training on searching equipment. One week's training on ECIC procedures.

Wage Rate - \$1.50 per hour (1953)

(2) Job Title - Card Punch Operator

Job Description - Punches the coded ECIC data from data sheets into cards.

Requirements - High school diploma. Typing ability. One week's training in ECIC procedures and machine operation.

Wage Rate - \$1.37 per hour (1953)

Clerks

(1) Job Title - Transmitting Clerk

Job Description - Transmits outgoing information by designated means (letter, telephone, teletype, etc.).

Requirements - High school diploma. Few days' training in ECIC procedures.

Wage Rate - $1.37 per hour (1953)

(2) Job Title - Receiving Clerk

Job Description - Checks incoming messages; sorts and transmits them to appropriate ECIC persons for processing. (In a small unit, this job could be combined with that of Transmitting Clerk.)

Requirements - same as for transmitting clerk

Wage Rate - $1.37 per hour (1953)

(3) Job Title - Filing Clerk

Job Description - Files all papers except punched cards.

Requirements - High school diploma. Few days' training in ECIC filing system.

Wage Rate - $1.00 per hour (1953)

Miscellaneous

(1) Job Title - Reply Writer

Job Description - Takes the information from selected cards; does necessary decoding and converting of units; puts information in proper form to be sent to inquirer.

Requirements - High school diploma. Typing ability and proficiency in arithmetic.

Wage Rate - $1.37 per hour (1953)

(2) Job Title - Messenger

Job Description - Carries mail and messages within the ECIC group.

Requirements - Ability to read, write, and follow instructions, normally a high school graduate.

Wage Rate - $1.00 per hour (1953)

The number of persons required in each occupation could be determined definitely only after some operating experience of a center. Some of the factors involved would be:

(1) The number of messages received daily

(2) The distribution of incoming messages between input data and inquiries

(3) The percentage of complex inquiries received, as distinguished from the more routine variety

(4) The condition of the incoming data, on the average — in other words, the amount of technical supervision required to process them.

The question of the number of personnel required as an operating cost factor is discussed in Part IV, page 122.

PART II

THE PROBLEM OF DATA COLLECTION

The first major job required of an ECIC, before it could provide a question-answering service, is that it collect the available data on electronic components for insertion in the files. This will be a large task, and some of its ramifications have yet to be explored. Some of the problems that have been foreseen are discussed in this section.

The principal effort for at least the first year would probably be the collecting and processing of the data on a few selected component groups. These would provide the raw material for evaluating (1) the system's over-all usefulness and (2) the efficiency of each of its elements. Thereafter, on these groups, it is expected that new and revised data on existing products and data on new products would be submitted to the Center on a routine basis. How this might work is illustrated by the pictorial presentation in Figure 7.

The most reliable performance data on electronic components, as on any product, are obtained through extensive laboratory tests, supplemented and verified by field tests, storage history, and operating-experience records. The amount of such information determined by a manufacturer or user on a newly designed product depends largely upon:

(1) The consequences of the product's failure in service — usually the likelihood of such failure's causing loss of lives, large amounts of money, and business for the manufacturer

(2) The cost of making the tests and of collecting and evaluating the data

(3) The time required to evaluate the performance characteristics

(4) The time available before the product must be in use to accomplish the purpose for which it was designed.

Somewhere along the line, for each new product, someone must decide upon the proper balance among these considerations. These decisions determine the amount of data that may be collected on the product eventually. In the case of electronic components, it is hoped that all such data pertinent to design considerations may be inserted in the ECIC files eventually.

Sources of Data

But where will the information be found? The first places to look, of course, would be in the manufacturers' catalogues, design details, test records, and field service reports.

The next likely places would be users' test reports and service records. Where the prime purchaser is a government agency, the latter's acceptance test reports are a valuable source of data, whether the tests were made in the manufacturer's own plant or in a government or privately owned testing laboratory.

Catalogue information will be comparatively easy to obtain, but not all of it will be easy to interpret accurately. Often the test data presented in catalogues are not accompanied by designations of the test methods used. Sometimes the nomenclature is not clear, and complete definitions seldom are included. In many instances, the units used in test values have more than one possible interpretation. Therefore, most catalogues are good sources for only such information as manufacturer, catalogue number, component name, primary ratings, weight, dimensions, appearance, and, sometimes, materials used and price.

Performance characteristics, especially those concerned with out-of-the-ordinary operating conditions, are in the realm of hard-to-get data. Some of the reasons for the difficulty are:

(1) The test specimens used in determining the characteristics may not have been representative.

(2) Proven test methods may not always exist.

(3) The data may be filed in some obscure location or may be lost.

(4) Many of the tests necessary to provide the needed data may not have been made at all, due to the time and expense involved. This would make further test programs necessary.

(5) "Life" tests, those valuable, yet often-lacking, evaluations, are nearly always expensive and time-consuming, and they usually destroy the specimens.

One probable result of ECIC operation would be to highlight the need for acquiring more and better performance data on electronic components.

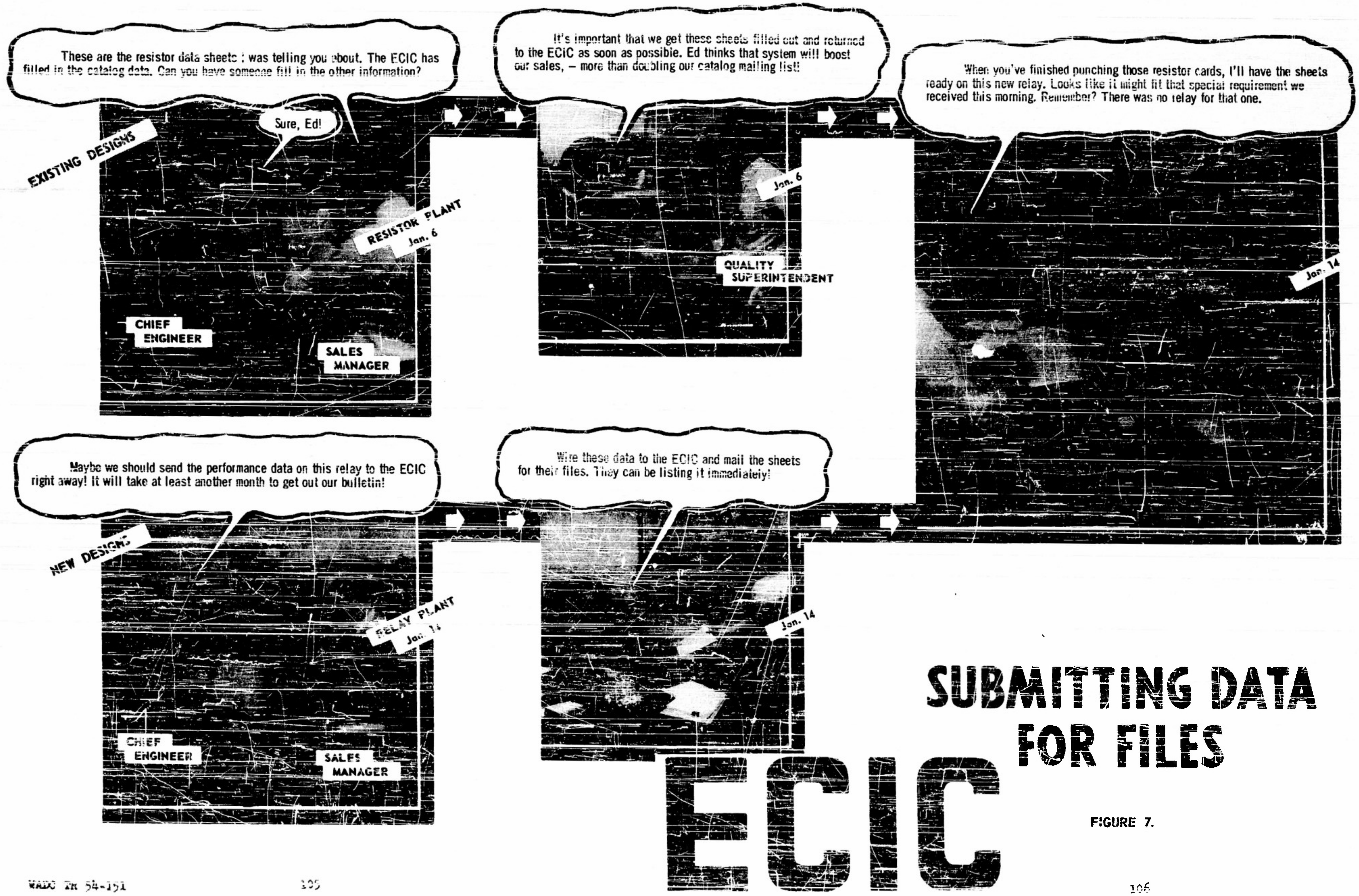

These are the resistor data sheets I was telling you about. The ECIC has filled in the catalog data. Can you have someone fill in the other information?
Sure, Ed!
EXISTING DESIGNS
RESISTOR PLANT Jan. 6
CHIEF ENGINEER
SALES MANAGER
It's important that we get these sheets filled out and returned to the ECIC as soon as possible. Ed thinks that system will boost our sales, – more than doubling our catalog mailing list!
Jan. 6
QUALITY SUPERINTENDENT
When you've finished punching those resistor cards, I'll have the sheets ready on this new relay. Looks like it might fit that special requirement we received this morning. Remember? There was no relay for that one.
Jan. 14
Maybe we should send the performance data on this relay to the ECIC right away! It will take at least another month to get out our bulletin!
NEW DESIGNS
RELAY PLANT Jan. 14
CHIEF ENGINEER
SALES MANAGER
Wire these data to the ECIC and mail the sheets for their files. They can be listing it immediately!
Jan. 14
SUBMITTING DATA FOR FILES
ECIC

FIGURE 7.

Yet, if manufacturers' test reports and government and other laboratory records were searched meticulously, and further tests were made to provide the missing parts of the necessary data, the complete picture of a component's performance could be documented and stored. With the ECIC acting as a clearing-house for reliable component data, a user of the ECIC should be able to confine his test programs primarily to the assembled equipment; he could reduce the proportion of time spent on component testing. Should minor changes in design or materials for a component be made, only parts of the testing program would have to be repeated. The resulting data could then be added to the existing punched-card information on that component. Major changes in design probably would result in the manufacturer's designating a new component, the original one being classed as obsolete. To enter these data, a new set of cards could be punched. Both new and revised information could be made available to all prospective users soon after being transmitted to the ECIC.

Methods of Obtaining Data

Until the ECIC became well known, the input data would have to be collected by ECIC personnel making direct requests (letter, wire, or telephone) to prospective sources. Some of the requests would have to be followed by personal visits.

It appears that the most effective initial procedure would be to ask manufacturers, and certain outside laboratories, to supply only those data that are not in catalogues. Catalogue data may be obtained, as in the past, through the normal channels. Tabulations of all data approved for punching on cards could be sent to the manufacturer for verification. The bulk of communication in the early stages of ECIC operation could be done by mail and personal visits, with use of telegraph, teletype or telephone where greater speed was advisable. It is expected that the teletype and letters would be used to a greater extent under full-scale operation of the Center, when only data on revisions or new products would be coming in.

Aids to this data-collecting job have been devised. Data Collection Sheets, such as those shown on pages 83 through 91 for capacitors, have been designed to simplify entry of data for each component. These sheets combine parts of the ECIC codes, data-insertion sheets, and definitions. The same technique could be applied to the other component groups. These data sheets, together with detailed instructions, could be sent to the various data sources with the requests to have the data filled in.

The design of these ECIC data-insertion sheets is such that the work required to fill in the data would be the minimum consistent with completeness and accuracy. For instance, the person filling in the data is not

asked to convert units to the ECIC standards, but only to indicate which units he has used. Most items can be answered with a single number, a single word, or merely a check mark. The work would require supervision by an engineer familiar with the component in question, but an engineering aide or technician could handle the details.

Compared with getting out a new brochure or catalogue, for instance, supplying data to the ECIC would be a comparatively simple job. (This statement does not imply that contributors to the ECIC data files could do away with catalogues, but merely gives some idea of the relative efforts involved.) Once the ECIC were in full-scale operation, it is expected that submitting data would become largely routine.

Educational Program Essential

It is well recognized by all concerned that sufficient input data to make an ECIC question-answering service practical cannot be collected overnight. The system's advantages to industry and to the Armed Forces must be demonstrated and publicized first. A thorough educational program would be necessary to interest all those whose electronic-component data should be entered in the ECIC files. Some will have to be shown that an ECIC would:

(1) Be an asset to their business

(2) Deal in facts, and not in opinions

(3) Not disclose information concerning any manufacturer's product that could be used to advantage by a competitor

(4) Be a worth-while contribution to industrial and economic progress

If the small sampling of opinion already made is any indication, education — not argument — will be the chief ingredient required.

PART III

DEVELOPMENT OF TEST METHODS

Two unrelated test-method-development programs were included in the research project: (a) automatic testing of resistors, and (b) life testing of resistors. Their objectives were separate and distinct, and they were carried on during different periods. The first was performed during the first nine months of the project – January, 1949, through September, 1949. The objective of this work was to develop and construct equipment (1) to test electronic components and (2) to record the data obtained, all automatically. The other testing phase was in effect between October, 1950, and November, 1952. Its objective was to develop methods of testing components whereby test data under unusual operating conditions could be obtained.

Development of Methods for Automatic Testing

The result of the work devoted to automatic testing of components was a prototype testing system, Figure 8. This system consisted of (a) an environmental chamber to condition components, (b) a hopper or test rack to hold resistors inside the chamber and automatically feed them in sequence to the measuring leads, (c) a method of measuring, consisting of a bridge to determine the resistance value of the resistors, (d) an indicating recorder to prepare a permanent record of the measurements made, (e) an analyzer to count the number of units with values that fall into selected brackets, (the analyzer also helps prepare the data for transfer to a card-punching unit), and (f) a card-punching unit to punch the values read by the bridge into machine-punched cards. (The card punch used in the prototype was a Remington Rand Model 3 punch).

The first testing phase of the contract was concluded upon completion of the prototype automatic testing system. Details of the equipment and its development, including sufficient information to reproduce it, may be found in the following reports on Contract AF 33(038)-1229:

First Interim Engineering Report, February 28, 1949, pages 9 through 11
Second Interim Engineering Report, April 28, 1949, pages 19 through 24
Fifth Interim Engineering Report, October 28, 1949, pages 76 through 86 and 89 through 95
Eleventh Interim Engineering Report, October 28, 1950, pages 267 through 271

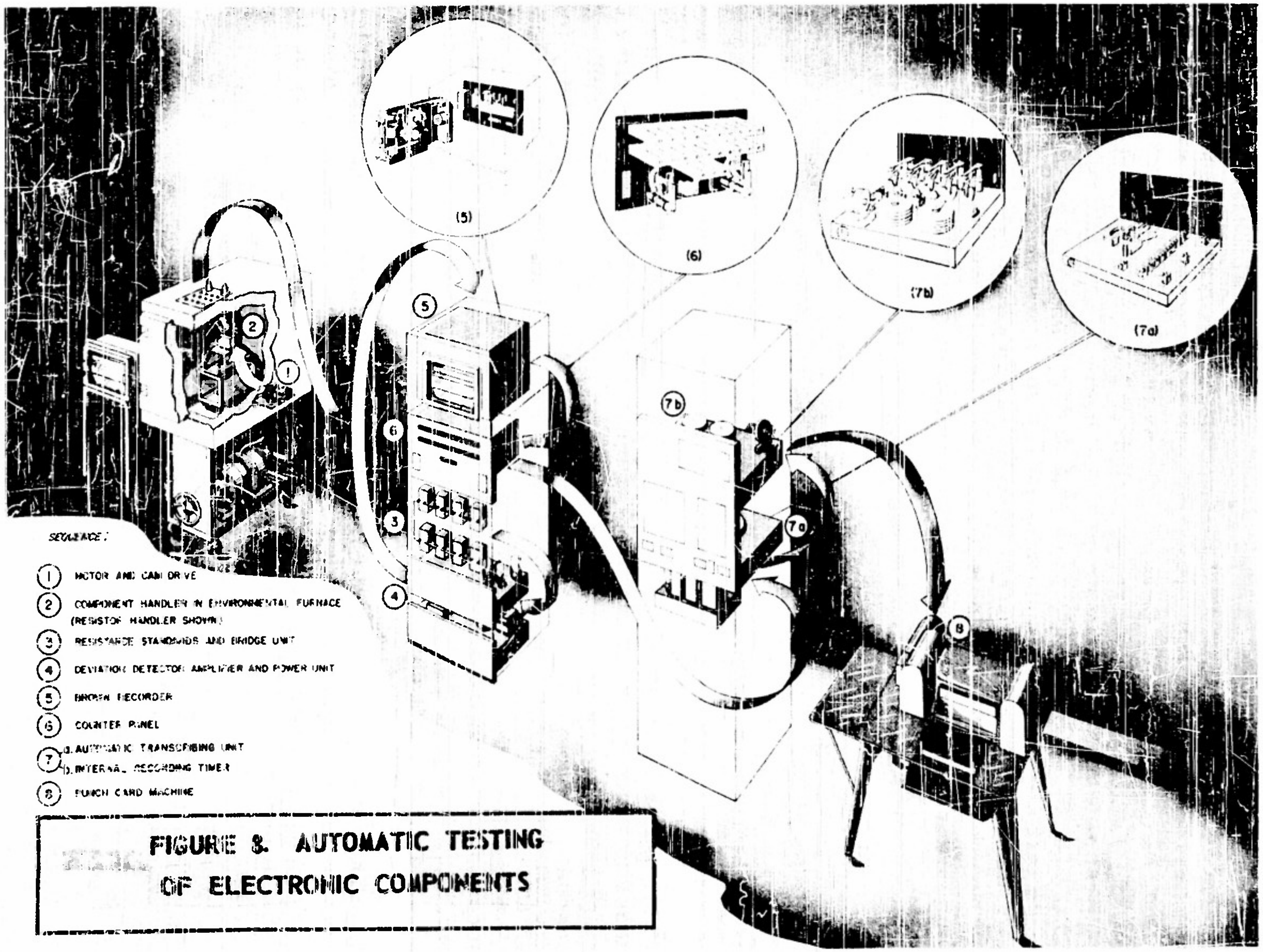


FIGURE 8. AUTOMATIC TESTING OF ELECTRONIC COMPONENTS

Development of Test Procedures to Determine Life Ratings of Electronic Components

Means of predicting composition-resistor life at high ambient temperatures were studied first under the program to develop life-test specifications. Use was made of short-time, small-sample testing methods. Statistically designed life tests and temperature-coefficient measurements on approximately 400 composition resistors were made at no-load conditions in the 100 to 300 C temperature range.

A second study was made on the dependence of the electrical characteristics of capacitors on temperature. Capacitance, dissipation factor, d-c resistance, and dielectric absorption were the criteria tested over the temperature range of 100 to 250 C. Two types of capacitor were tested: 1000-$\mu\mu$f molded-mica, and 500-$\mu\mu$f tubular impregnated paper.

Details of the work on test-procedure development are contained in the following reports on Contract AF 33(038)-1229, RDO No. R-112-140:

Thirteenth Interim Engineering Report, September 30, 1951, "A Study of the Prediction of Composition-Resistor Life"
Supplement to the Thirteenth Interim Engineering Report, February 29, 1952, "A Study of the Prediction of Predried Composition-Resistor Life"
Fourteenth Interim Engineering Report, October 30, 1952, "A Study of the Behavior of Capacitor Characteristics at Elevated Temperatures"
WADC Technical Report 53-349, July 1953, "A Test Procedure for Short Life Rating of Composition Resistors"

Objectives and Problems With Reference to Resistors

The long-range objective of this work was to establish a set of procedures for predetermining the short-term life of electronic components operated under any conditions of ambient temperature, load, altitude, humidity, and vibration. In the process of study and development on this problem, and in the evaluation of the procedures developed, many new problems were uncovered. Ideas and guides for solving or circumventing these problems were conceived. Many of these guides or methods of attack are general; i.e., they could be applied to many electronic components. This section discusses the more important of these problems and offers suggestions and general guides for the extension of these procedures to other electronic components.

The major problems encountered in the establishment of short-term-life testing procedures for composition resistors were:

(1) The many combinations of variables influencing life

(2) Definition of life

(3) The wide variability of life

(4) The difficulty in achieving truly representative sampling

(5) The large effect of component storage history and conditioning methods on life.

Variables Influencing Life. Perhaps the most difficult problem confronting the ECIC-system planners is the multitude of variables that influence the life of electronic components.

Suppose we wish to obtain the life of a component under the following conditions:

(1) Ambient temperature: 40, 100, 140, 180, 220, and 260 C

(2) Load: 0, 1/2, 1, 1-1/2, and 2 times rated load

(3) Altitude: 0, 30,000, and 60,000 feet above sea level

(4) Humidity: 0 (low) and 95 to 100 per cent relative

(5) Vibration: 0, 50, and 100 per cent of some maximum vibration amplitude

(6) Storage history: moisture-conditioned, indeterminate (after a year or more of typical storage), dried, and kept in a desiccator.

It would be unrealistic to test all the conditions of one variable at only one particular value of each of the other variables. There is no assurance that a relation between temperature and life, established at sea level, will hold true at an altitude of 60,000 feet. There are many known "variable interactions".

To determine the life of the component under all combinations of the above test conditions would require 6 x 5 x 3 x 2 x 3 x 3 = 1620 tests to be performed. If only ten components were used to establish mean values for each test, 16,200 components would be required. The number of components to be tested becomes important with expensive components, since

most life tests destroy the specimens, but the major cost of the 1620 tests would be the time and effort required to perform them (considering that these are <u>life</u> tests). *

The ideal testing program would be a compromise between the two extremes. The program should be extensive enough to provide useful and accurate information, yet not require an impractical amount of testing. It is believed that any approach that eliminates a large amount of testing by supplying conservative (rather than "actual") life data is preferable, if the loss of information is not too great. The basic approach used for the resistor test procedure is consistent with this philosophy. The test procedure presented in WADC Technical Report 53-349 for composition resistors is the result of such a compromise. This procedure requires only 1500 resistors of a given size, type, and manufacturer. This approach is summarized in the following paragraphs.

Almost all of the life testing prescribed in the detailed procedure is to be carried out under temperature stress alone. Curves of life as a function of temperature at no load are to be obtained and will provide the basic life information. Then, by a series of "load versus altitude" tests, which are not life tests, surface temperature would be obtained for the resistor as a function of load and altitude. A few load-life tests are to be made then under the most severe conditions likely, and a temperature factor of safety, to be applied to the surface-temperature data, is to be obtained. The latter would be done by comparing the no-load temperatures required to produce the same life-times with the measured surface temperatures. To ensure conservative results, the temperature factor of safety would be obtained under severe load and altitude conditions, from the viewpoint of producing maximum temperature rise in the resistor.

Humidity and vibration are considered in this procedure only to the extent of determining whether the lives are affected by these variables. If it develops that these variables greatly influence the life of most resistors, it is suggested that severe vibration and/or humidity stress levels be selected and applied throughout the no-load life tests; the results obtained should then be conservative for almost any other values of humidity and vibration.

Starting-point information for all the life testing is obtained by running a 1-hour no-load temperature-stress step test.** Next, high-temperature short-term lives are determined, and then the more expensive long-term tests are conducted. This sequence leads to efficient use of the knowledge gained at the shorter lifetimes.

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* Over-all experience in specification testing by the Armed Forces indicates that average labor costs are of the order of 10 man-hours for <u>each</u> component tested.

** Jerencsik, A. P., and Sackett, W. T., Jr., "The Stress-Step Method of Obtaining Short-Term Life Ratings on Electronic Components", Proc. Natl. Electronics Conf., <u>8</u>, 267 (1952).

A further viewpoint in developing the procedure has been that tests should be designed with the probable applications in mind. Since few applications call for continuous operation of resistors beyond 8 hours, all testing for longer lifetimes is set up for cycling. A basic stress cycle of 2 hours "on", 1/2 hour "off", was adopted here. Any choice is necessarily arbitrary. Furthermore, the "off" period is not critical and, with proper precautions, can be increased to avoid round-the-clock testing.

Defining Life and Variability of Life. One of the first requisites in life testing is to arrive at a reasonable definition for life. For a fixed resistor, the property of major interest is the resistance value. A secondary property that may be of importance in some applications is the noise generated by the resistor. Almost all other components have more characteristics that must be considered. For example, a capacitor has the properties of capacitance, dissipation factor, leakage resistance, absorption, and break-down strength, any one or all of which may be used to set up critera for life.

One of the most frequently heard suggestions for defining life is that "when a component exceeds its tolerances in any property, the life is ended". Although any definition selected will be arbitrary to some degree, such a definition may be illogical. Composition resistors have specified tolerances of ± 5, ± 10, or ± 20 per cent. However, there is usually no difference among these three classes of resistors other than resistance tolerance. In fact, the 5 and 10 per cent resistors usually are obtained by automatic sorting, leaving a break in the center of the distribution curve of the 20 per cent resistors. Thus, in the deterioration process, some resistors would have only a few per cent change to exceed tolerance, but others could change by 20 per cent before exceeding tolerance. This would add several orders of magnitude to the variability in lives and thus detract from the value of the life ratings.

Some general considerations to be kept in mind in choosing a life definition are:

(1) The most critical property (the one that changes most with least operating stress) should be considered.

(2) The definition should be related to the deterioration process; reversible changes, such as those due to temperature characteristic, should not enter into the life definition.

(3) Other things being equal, relative quantities, such as percentage change in critical characteristics, should be chosen so as to give the least variable lifetimes, as well as "reasonable" life values.

Figure 9 portrays the typical behavior, under temperature stress, of a resistor manufactured by Company "A". The surface temperature of the resistor (following insertion in an oven held at T degrees) is shown in the upper curve. The resistance as a function of time is shown in the lower curve.

The portion of the lower curve from a to b is reversible, and this variation should not enter into the life definition. A satisfactory definition would be the time $(t_2 - t_1)$ required for an x per cent change in resistance from the initial value after temperature equilibrium is reached at b. In many cases, the designer may not be able to tolerate the magnitude of the reversible change in resistance with temperature from a to b in his application. However, this type of decision is independent of the life of a resistor and may be determined in a straight-forward manner, without life testing. Typical data of this type are shown in Figure 10.

In the procedure that was followed, 5 per cent change was chosen arbitrarily as the criterion for life of a composition resistor. Some of the experimental resistor work indicated that a lower value, say 1 to 3 per cent, would have given less variable life data. The data are not conclusive, however, and a low per cent change requires more accurate resistance measurements. It is almost certain that lower percentage values will be in order for carbon-film and wire-wound resistors.

Representative Sampling. Destruction of samples that are life tested makes statistical methods of testing imperative. Further, the samples chosen must be representative of the manufacturer's production, in order for results to be meaningful. The immediate question is "How may representative samples be obtained?" (Manufacturers of resistors could offer no easy answers when consulted on this problem).

The major difficulty is that the short-term, high-temperature life of resistors is not controlled by the manufacturer. Hence, there is no assurance that batch changes will not produce radically different short-term-life characteristics. The only way so far envisaged to overcome this problem is to sample at successive intervals of time and to check continually at least one very short-term life (such as 1 hour) and one relatively long-term life (such as near 50 hours) on the successive samples. The reason for the two tests is the probability that different mechanisms of failure are operative at the higher and lower temperatures. Then techniques of calculation based on quality-control procedures would allow assignment of minimum values for the characteristics. This testing at intervals would have to continue, unless the manufacturer were in a position to bring these characteristics under control.

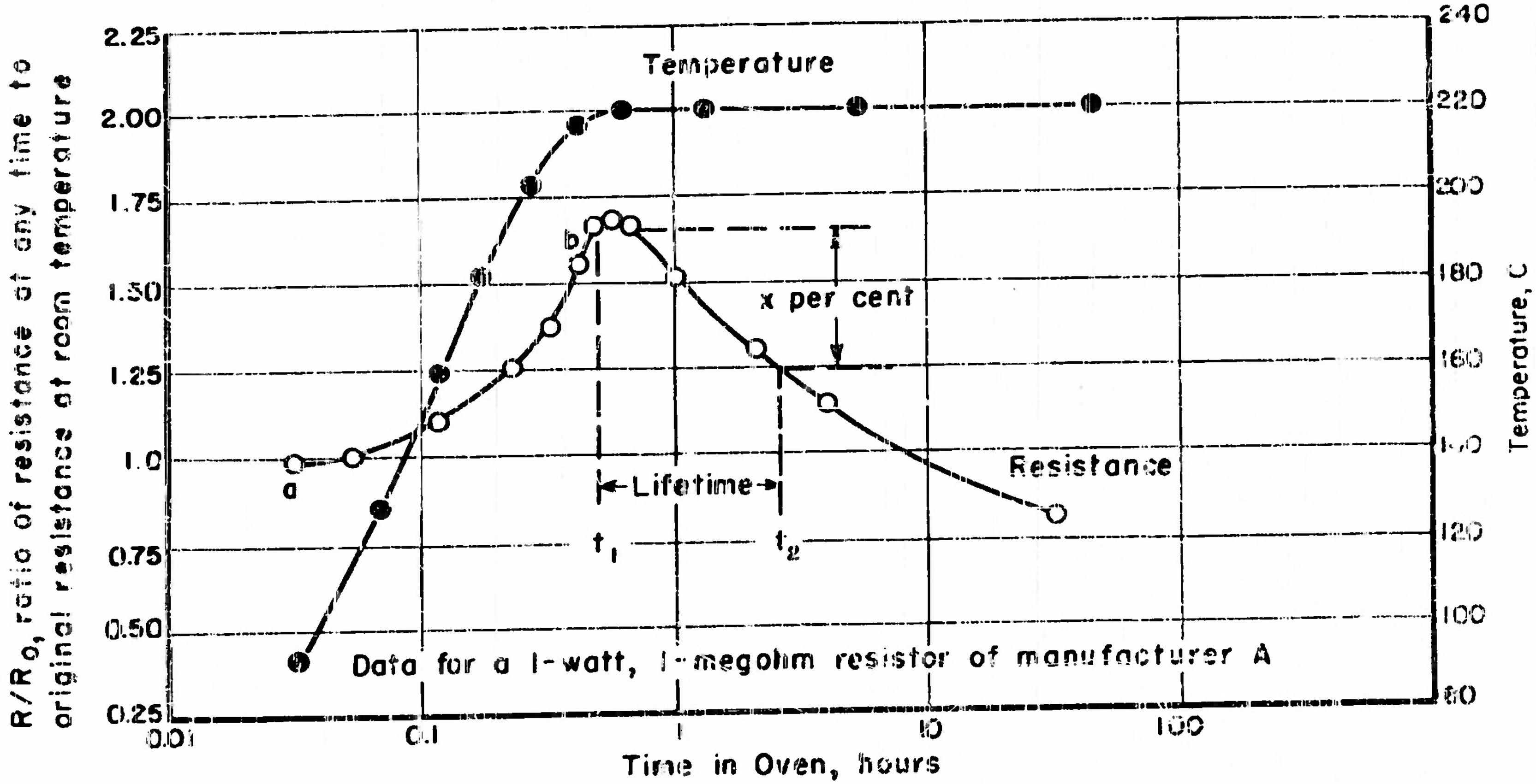

FIGURE 9. RESISTANCE AND TEMPERATURE AS FUNCTIONS OF TIME FOR AN "A" RESISTOR BAKED AT 220 C

A-7114

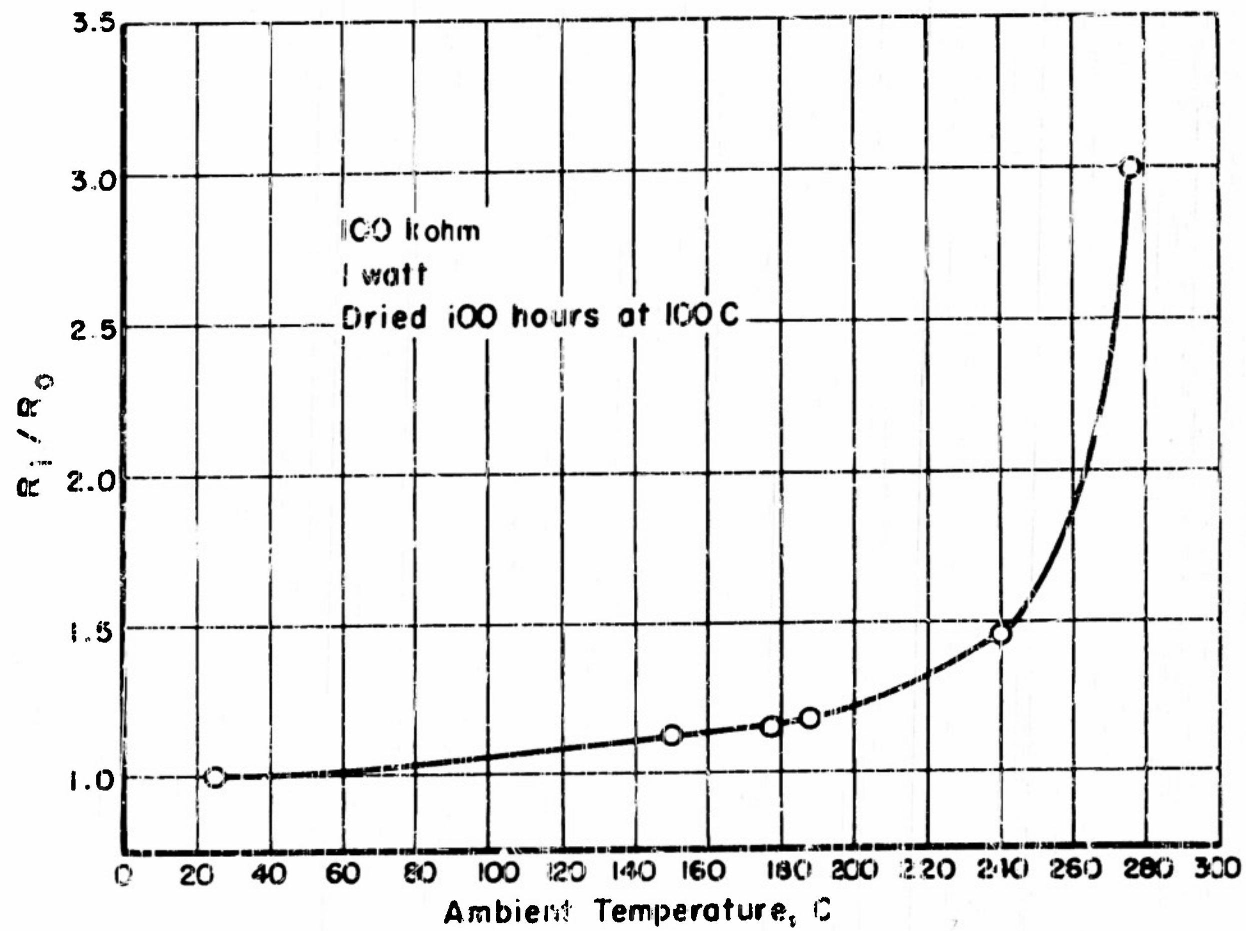

FIGURE 10. RESISTANCE - TEMPERATURE CHARACTERISTIC FOR "A" RESISTORS, NO LOAD

A-7134

Storage History and Conditioning Methods. In assigning life ratings, it would be most desirable to avoid entirely the problems of conditioning resistors. The obvious argument is that any ratings assigned should apply to all resistors, regardless of their past history, not merely to resistors that are kept "bone dry". This argument presents several difficulties. The primary difficulty is that the moisture content radically influences the short-term life, the temperature characteristics, and the variability of these quantities. Further, high moisture content makes the resistor's short-term life closely dependent on slight variations in the testing procedure. For example, the life of resistors with high moisture content becomes extremely sensitive to the initial rate of rise to the temperatures.

One problem here results from the different materials and fabrication techniques for producing various composition resistors. Some manufacturers use a wax coating to protect the resistors from moisture effects. As long as this coating keeps out the moisture, the resistor needs no conditioning. However, once exposed to temperatures high enough to disturb the coating, the resistors become susceptible to moisture effects.

In general, much longer lives at high temperatures are obtained on dry resistors than on moist ones. A life rating obtained without specifying the moisture conditions of the resistors would be of little value.

Consider this example. Suppose new, wax-coated resistors, well dried before coating, were tested without conditioning and gave a life rating of 10 hours at full load and 200 C ambient temperature. Then suppose that a missile designer decided these resistors were good enough for his applications. Later, several hundred missiles were manufactured, given final ground checks, and then stored against the day of need. Now, assume that the storage conditions on ground-operating checks produced temperatures sufficiently high to damage the wax coatings of the resistors. Subsequently, storage allowed the resistors to absorb an appreciable amount of moisture. With this absorbed moisture, the average life at full load and 200 C would be on the order of 1/2 hour. Hence, when fired, a large proportion of the missiles might fail to operate correctly.

This hypothetical illustration shows the need for caution in the establishment of procedures and life ratings for high-temperature use. The conditioning problem must be faced.

It is recommended that temperature characteristics and life ratings be obtained on both dry resistors and moist resistors. Dry resistors should be obtained by conditioning resistor samples at 105 ± 5 C for 100 hours, and then storing them in a desiccator until tested. Moist resistors will be obtained by first subjecting them for 1 hour to the highest temperature at which they are likely to be used (to stress whatever coatings may be present), then subjecting them to 50 C at 95 to 100 per cent relative humidity for at least

250 hours, and storing them in this environment until the tests begin. Life ratings will then specify the moisture content (as "dry" or "moist") of the resistors to which they pertain. It will also be necessary to obtain check measurements on resistors in the "as-received" state, which will be one of indeterminate moisture content. This will assure that neither of these procedures improves the resistor quality (for example, by further curing of partially cured resins used in the composition).

Summary and Problems With Reference to Capacitors

It is believed that the information obtained on the capacitor program gives adequate assurance that life rating of capacitors is possible in certain areas of operation. The possibility of developing procedures for rerating capacitors for all applications, however, does not seem feasible.

The rerating of capacitors for applications for which the capacitance values are critical does not seem to be practicable. This would include such applications as precision wave filters, in which the capacitance value must be known with an error of less than 1 per cent. The variability of the temperature coefficient of capacitance is too large for such precise prediction. However, high-temperature conditioning decreases this variability considerably, so that the possibility should not be discounted completely.

In such applications as power-supply filters, in which the capacitance value is not critical, life rating could be accomplished with very little effort. In filtering applications, large variabilities in capacitance, leakage resistance, and dissipation factor could be tolerated. The leakage resistance probably could decrease to values as low as 10 megohms, and the dissipation factor increase to as much as 10 per cent, without seriously affecting circuit operation.

Life rating for other applications in which the capacitance value is not critical also seems feasible. In a coupling application, a fairly large increase in capacitance could take place without seriously affecting circuit operation. In this application, the limitations on the decrease in capacitance would have to be more exacting, as such circuits usually are designed to rather close tolerance. For this reason, too large a decrease in capacitance would attenuate the signal considerably. Leakage resistance is critical in this application, but it is believed that a reduction to a resistance value at least 100 times as great as the resistance of the grid resistor could be tolerated without seriously affecting operation. Capacitor noise should also be considered in evaluating capacitors for this application.

The possibility of devising accelerated tests to reduce the amount of testing required for obtaining rating information seems well worth investigation. In such a testing program, quality criteria would have to be

investigated and evaluated. The rates of deterioration observed under one condition might very well be extrapolated to include other conditions. Trends, such as the rate of decrease in quality as a function of temperature, should be evaluated. Sufficient data were obtained in the tests performed on this program to show that the rates of variations of the measured characteristics were dependent on temperature. Further investigations would have to be made to determine whether these variations followed any set pattern that would render them predictable.

Absorption and dissipation factor appear to be the natural phenomena for describing capacitor quality. Absorption is a difficult and time-consuming characteristic to measure. The results obtained are relative, and can have meaning only if correlated with applications, and if interrelated with other characteristics. In the study of impregnated-paper capacitors, capacitance, dissipation factor, and d-c resistance were affected by changes in the absorption properties. Therefore, the study of absorption should be made by observing its effect on the other characteristics.

The dissipation factor, as measured, is a result of two types of loss that take place in the capacitor — the absorption and the conduction losses. The amount of absorption cannot be evaluated by means of its effect on capacitance because of the variable time factor involved in bridge measurements. However, observation of the leakage-resistance behavior is a very good means. The steady-state value of the leakage resistance will provide information on the portion of the dissipation factor that is attributable to conduction. The rate of change in leakage resistance will provide information on the absorption.

Rapid changes in absorption and dissipation factor, caused by the removal of moisture and volatile materials, have already been observed in studies of capacitor quality. It is believed that testing these characteristics will measure slow deterioration.

The task of establishing short-time-life ratings on capacitors is indeed a huge and complicated one. Much further work must be done, preferably of a fundamental-study nature, since the dielectric problem is the key to the life-rating problem on nearly all other components.

Guides and Suggestions for Extension of the Short-Time-Life Rating Procedures to Other Components

Carbon-Film and Wire-Wound Resistors. It is believed that these procedures can be extended directly to carbon-film and wire-wound resistors. However, it will undoubtedly be advisable to modify the percentage

change of resistance in the life definition to 1 per cent for carbon-film resistors and 0.5 per cent for wire-wound resistors. To do this, it will be necessary to increase resistance-measurement accuracy requirements to ± 0.05 per cent.

Variable Resistors. The extension of the procedures described to variable resistors, potentiometers, volume controls, etc., should be possible by prescribing that the no-load - temperature life tests be performed with a steady rate of rotation (or alternation) of the wiper blade. This rate should exceed likely service values. Contact noise becomes an additional property that must be studied, and perhaps used in the life definition.

Transformers. It is believed that electronic power transformers can be handled by procedures similar to those for resistors, with the complication that the dielectric properties of the insulation undoubtedly would be critical in the life definition. The basic philosophy of arriving at load-altitude-temperature lives (through no-load life data as a function of temperature and temperature-rise data) should apply. The no-load - temperature life data should be obtained under severe temperature-cycling conditions that stress (through expansion and contraction) any fine wire present.

With these more complicated components, the difficulty of separating catastrophic and gradual failures will become severe. The most promising hope of solution lies in a laboratory-study approach.

PART IV

ESTIMATED COSTS OF BUILDING UP AND OPERATING AN ECIC

An ECIC operating at full scale will require a large initial investment and a large budget for operation. These costs were estimated and are presented here for two separate methods of obtaining cost information.

The first method used in estimating costs was to consider the initiation and initial operation of the ECIC as a research problem. Then the costs were based primarily on the number of engineers estimated to be needed to set up and start operations of the ECIC system successfully for a single component. Necessary assistance, supplies, equipment, and other expenses were estimated on a per-component basis. These figures were totaled for all the components being processed at a certain time. By this method, it was possible to calculate the approximate total cost of build-up of the ECIC at any desired rate. A suggested program for the build-up is given, and the estimated costs tabulated.

The second method of estimating costs is based on an operational analysis of a fully operating ECIC. An operating model of the system was visualized and analyzed in detail. The rates of work of individuals and costs for each task were estimated. Two rates of usage of the over-all ECIC system by questioners were postulated, and costs were calculated for each rate.

The two methods provide estimated annual operating cost figures within about 20% of each other ($1, 540, 000 vs $1, 200, 000). Different approaches to basic cost elements account for most of the difference in the estimates. It should be noted also that the operational analysis used 100 per cent of direct labor costs for overhead, whereas the research approach used 45%. In the former, supervision and certain machine rentals were included as overhead. In the research approach, these items were classed as direct operating costs.

It should be understood that the figures presented in this section are estimates only. They were based upon operating rates considered to be as realistic as are possible without the benefit of full-scale operating experience. They refer to 1953 dollars. The figures are believed to give a reasonable picture, for planning purposes, of ECIC operational costs. They definitely show the sensitivity of the over-all cost to the various factors affecting it.

Costs of Build-Up and Initial Operation

Preliminary Remarks

It is obvious that an ECIC cannot be placed in full-scale operation instantaneously, regardless of the amount of money expended. It seems obvious, also, that there is a minimum rate of build-up below which gross inefficiencies and creeping obsolescence would preclude any practical effectiveness. Somewhere between these extremes lies an optimum build-up rate — determined by conditions such as a national emergency or available peace-time funds.

The lower limit of time required to put an ECIC into effective but limited operation would be that necessary to collect and process the existing data on a single component group — resistors, for example. It is estimated that the data on one component group could be inserted into an ECIC efficiently in a period of six months to one year.

There is a most efficient rate at which the ECIC can be built up. The controlling factor appears to be the procuring and training of personnel. However, it is unrealistic to assume that every detail of an operation as complex as that required for the ECIC could be anticipated correctly and planned in advance. For this reason, it would seem expedient, even if trained people were available, to build up the operations gradually, so that errors in techniques could be caught and corrected on a relatively small scale.

The cost figures provided here for initiating an ECIC are based on what is judged to be the most logical and efficient rate of build-up. They provide for adequate training and growth of the personnel staff and a parallel growth of operations, to permit adequate study of operating methods before a large commitment is made. The estimates provide for six months on-the-job training for a new engineer under supervision before he is allowed independent responsibility. It is assumed that he would then train a new engineer during each succeeding six months' period, while at the same time perform other necessary ECIC tasks. Thus, every six months the size of the ECIC staff could approximately double. If an initial operating nucleus of six engineers is assumed, the technical staff build-up would be essentially complete after 30 months. After about 42 months, the ECIC could be in nearly full-scale operation on all the widely used components.

The estimated costs of activating and operating a single component group for an ECIC are shown in Figure 11. The costs of building up and operating the ECIC for all components were obtained by adding the costs for the component groups being processed. These data are summarized in Table 4. Figure 12 shows a recommended rate of build-up of activity on

component groups. Figure 13 shows personnel requirements. Figure 14 illustrates how the cumulative monthly costs would rise at that rate. The rate is the one believed to be most efficient, as it provides for a comprehensive training program for new personnel.

It should be noted that, in actual practice, personnel would function more efficiently as the system grows. Therefore, the costs indicated in Figure 13 may be considered conservative and subject to revision downward. However, if a rate of build-up of an ECIC faster than that shown in Figure 12 is attempted, operating inefficiencies would occur during the early stages and the figures would have to be revised upward.

Details on Costs of Building Up an ECIC

Cost Requirements for a Single Component Group. The total estimated costs per component group and the various factors making up this total are shown in Figure 11. The following cost factors are included — manpower, overhead, machine purchase and rental, travel, technical services, and miscellaneous.

The manpower cost* from Figure 11 is $3550 per month per component group for the first year and $2125 per month for the second year. Overhead has been estimated at 45 per cent of these costs.

The estimated manpower and types of personnel required to build up an ECIC on a single component group are shown in Table 1. At least

TABLE 1. ESTIMATED MANPOWER REQUIREMENTS TO BUILD UP A SINGLE COMPONENT GROUP

Type of Personnel	First Year: Number of Man Years	First Year: Cost Per Month	Second and Following Years: Number of Man Years	Second and Following Years: Cost Per Month
Supervisory	3/5	$ 600	3/10	$ 300
Engineering	3	1950	1-1/2	975
Technician	2	700	2	700
Clerical	1-1/5	300	3/5	150
Total	6-4/5	$3550	4-4/10	$2125

*These costs include salaries; wages; accrued for vacation, holiday, and sick-leave pay; pensions; and social security.

three engineers would be needed during the first year for each component group, when data collection would be at a maximum, and question-answering service was just being set up. The necessary supervisory, technician, and clerical personnel would bring the total to about 6-4/5 persons.

During the second year, activity would consist mainly of question-answering service and of keeping the input-data file up to date. This would require about 1-1/2 engineers. Total personnel, including supervisory, technician, and clerical, would be about 4-4/10 persons. The number of technicians would not decrease during the second year, because they would be doing most of the routine work for the question-answering service.

The maximum cost of machine rental has been estimated at about $710 per month for a single component group during build-up of the files. As additional component groups are added, the prorated machine rental costs during build-up would decrease to about $270 per month per component group. Machine costs would be higher for the first component group than for later groups because the minimum number of machines could not be utilized to full capacity by the work on a single component group. The cost per component group would go up, however, during the second year, because more equipment would be required for question-answering service than for entering data. Although the costs shown in Figure 11 are for a single component group, the machine charges are based on the maximum estimated ultimate costs of $386 per month per component group. The estimated rate of machine use for activation and initial operation of an ECIC is shown in Table 2.

The cost of travel (required to acquaint the suppliers of data with ECIC and indicate the types of data needed) has been estimated to be $300 per month per component for the first six months, $150 per month for the second six months, and $100 per month after that.

The miscellaneous category covers costs of materials and supplies, such as punch cards, card cabinets, microfilm, special forms, and reports. This cost was estimated to be $150 per month per component group for the first year and $100 per month for the second year.

It may be seen that, after the backlog of data had been collected and entered, the operating costs per component group would go down.

Costs for Build-Up and Operation of a Complete ECIC. In order to obtain an estimate of the total cost of build-up and operation of the ECIC, the costs estimated for a single component group, Figure 11, were summarized for all component groups. For this purpose, it has been assumed that there would be a total of thirty-five component groups, as specified in the original statement of work for this project. Although a component

TABLE 2. ESTIMATED MONTHLY MACHINE-RENTAL PER COMPONENT GROUP FOR BUILD-UP AND INITIAL OPERATION

Name	Number of Components - First Year		Number of Components - Routine	
	First Component	Twelfth Component	First Component	Twelfth Component
Card punch				
Number of machines	1	1/3	1	1/6
Monthly rental	$60	$20	$60	$10
Card verifier				
Number of machines	0	1/3	0	1/6
Monthly rental		$20		$10
Electronic statistical machine				
Number of machines	1	1/8	1	1/4
Monthly rental	$242	$30	$242	$60
Sorter				
Number of machines	0	1/4	0	1/2
Monthly rental		$13		$25
Collator				
Number of machines	1	1/8	1	1/2
Monthly rental	$209	$28	$209	$105
Cardatype				
Number of machines	1	0 (1/2)	1	0 (1)
Monthly rental	$137		$137	
Tabulator				
Number of machines	0	1/12	0	1/12
Monthly rental		$67		$67
Card-to tape punch (5 channel)				
Number of machines	0	1/8	0	1/4
Monthly rental		$18		$35
Reproducer				
Number of machines	0	1/8	0	1/8
Monthly rental		$9		$9
Subtotal monthly rental	$648	$205	$648	$321
Teletype	65	65	65	65
Total monthly rental	$713	$270	$713	$386

	First Year		Second Year		
	Dollars Per Month	Dollars Per Year	Dollars Per Month	Dollars Per Year	2-Year Total, dollars
Miscellaneous	150	1,800	100	1,200	3,000
Travel, etc.	225	2,700	100	1,200	3,900
Machines	270	3,240	386	4,632	7,872
Overhead (45% of salaries and wages)	1,600	19,200	955	11,460	30,660
Salaries and wages	3,550	42,600	2,125	25,500	68,100
Totals	5,795	69,540	3,666	43,992	113,532

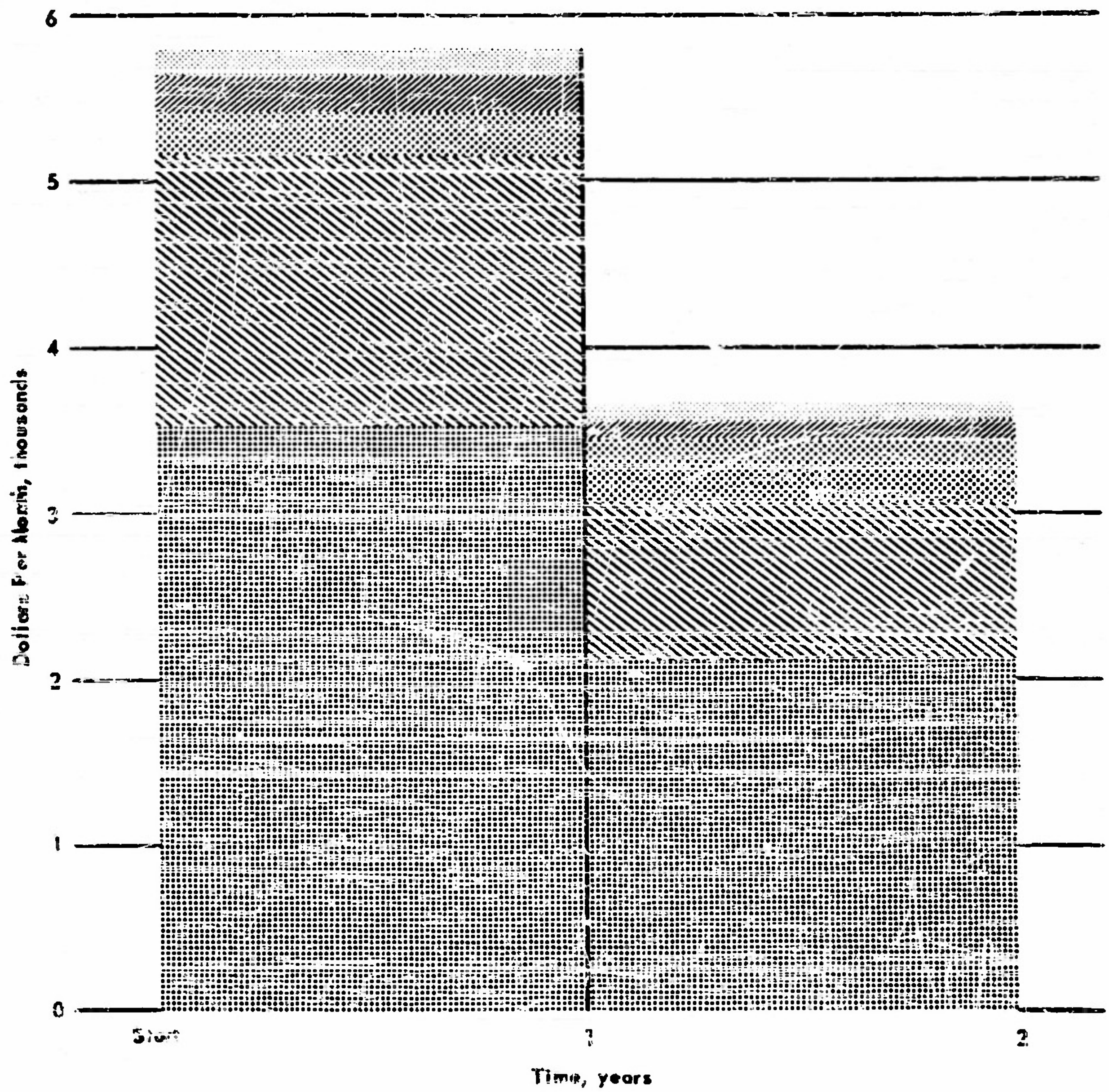

FIGURE 11. ESTIMATED COSTS OF BUILDING UP AND OPERATING AN ECIC FOR A ONE-COMPONENT GROUP ONLY

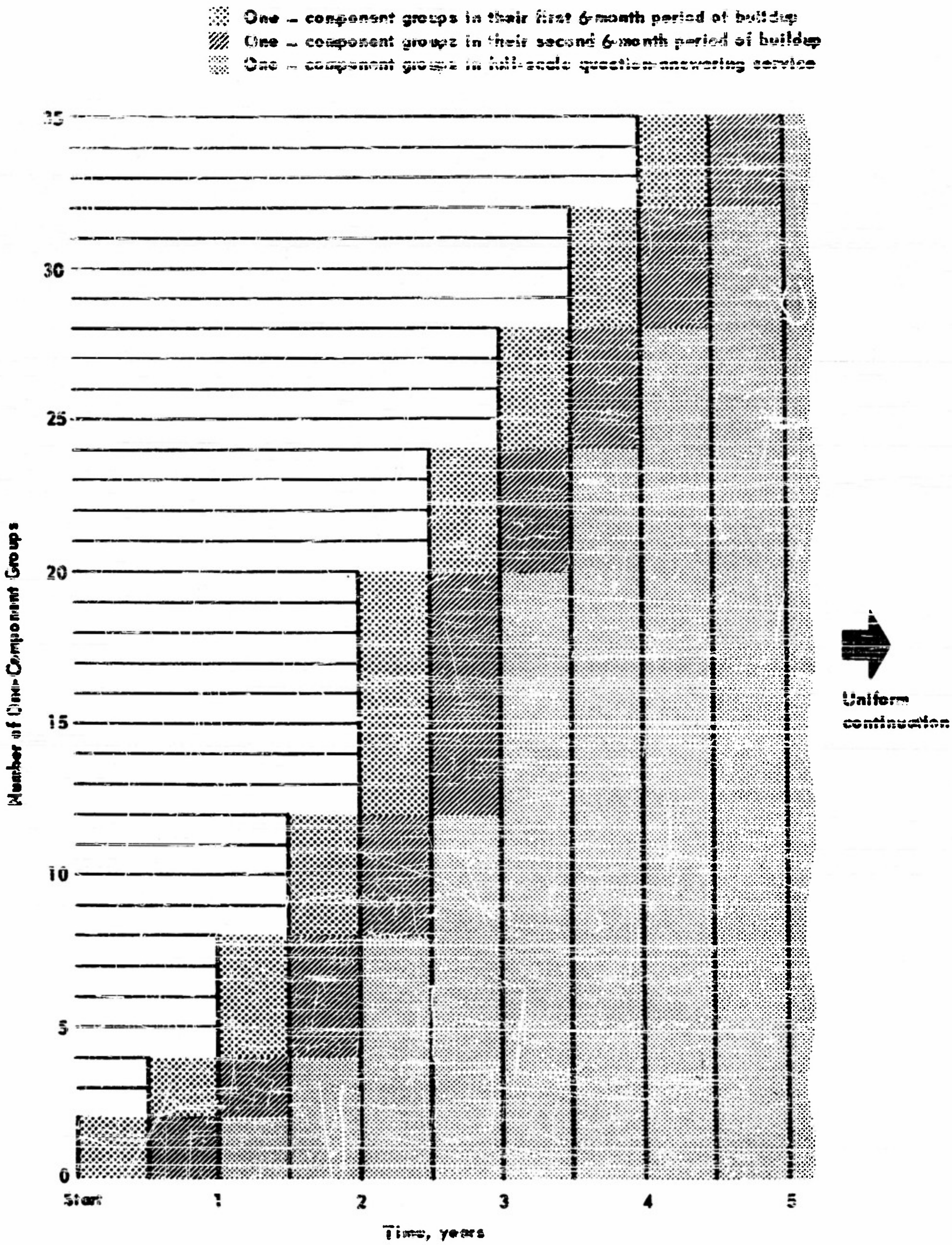

FIGURE 12. RECOMMENDED BUILDUP RATE OF AN ECIC
(Based on the Methodical Addition of One-Component Groups)

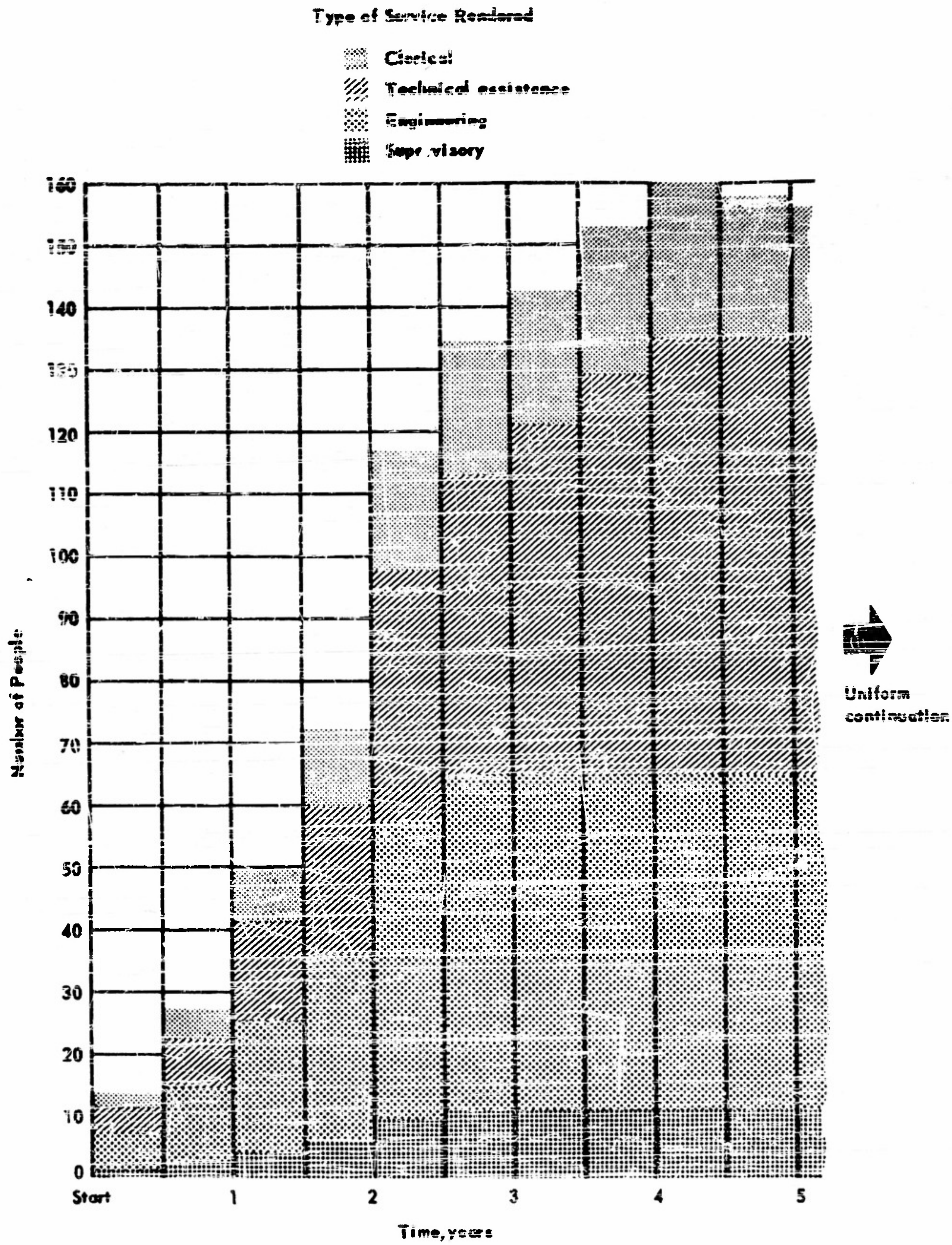

FIGURE 13. PERSONNEL REQUIREMENTS FOR AN ECIC (From Table 3)
[Using the Buildup Rate Recommended in Figure 12]

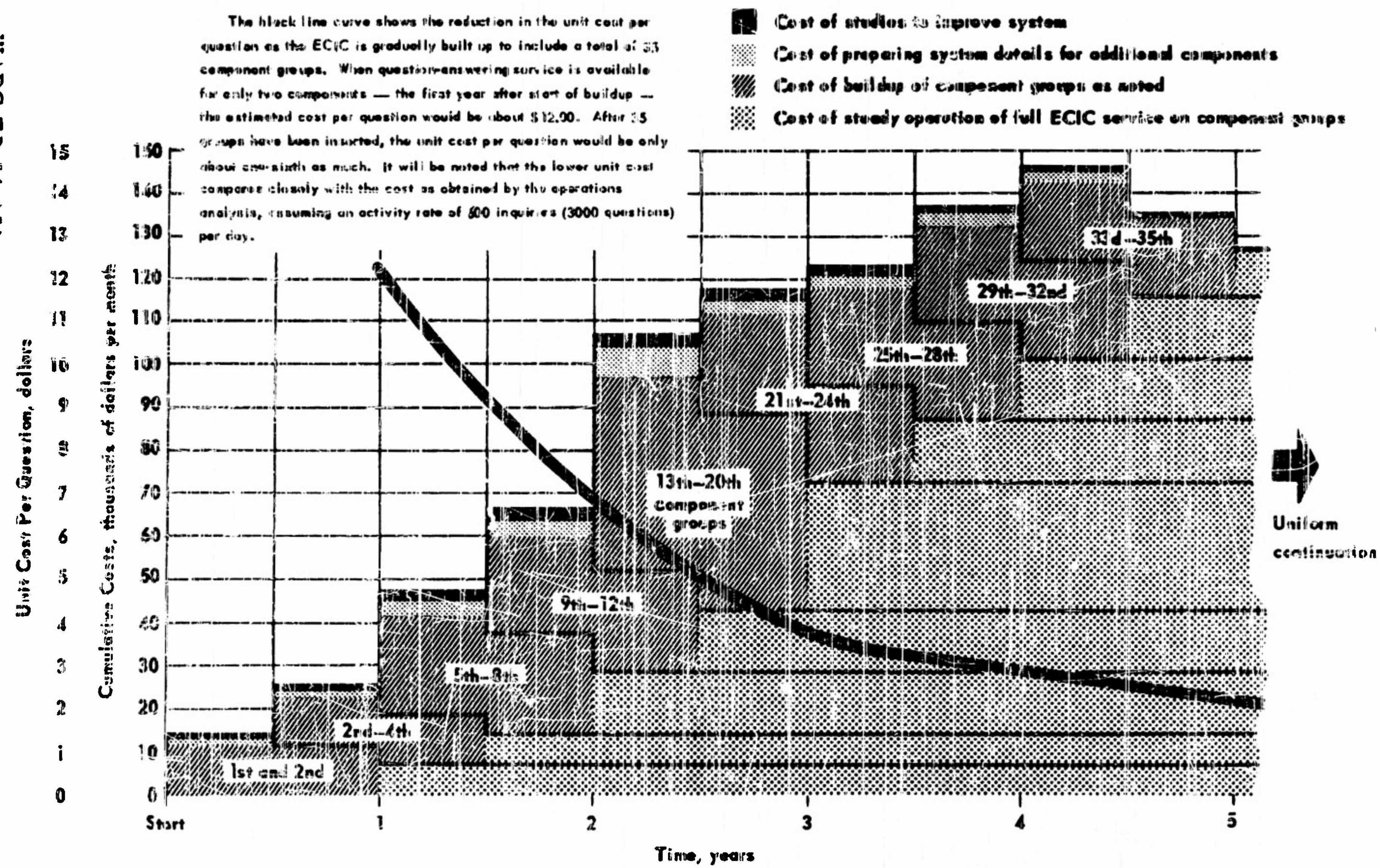

FIGURE 14. CUMULATIVE COSTS OF THE BUILDUP AND OPERATION OF AN ECIC
(Using the Buildup Rate Recommended in Figure 12)

group may be defined in various ways to give different numbers of component groups; the important thing is to make sure that all components are included eventually. Since the thirty-five component groups would include essentially all of the widely used components, the cost figures given here should be considered as applicable to all electronic components.

As mentioned earlier, there is a rate of build-up of components which, it is believed, would give the lowest over-all cost. This assumed rate is illustrated in Figure 12, and has been tabulated as the left hand parts of Tables 3 and 4. Figure 12 shows the number of components in each of three stages of build-up for each six months' period during the data-insertion phase of the ECIC. The three stages are:

(1) First six-month period of build-up
(2) Second six-month period of build-up
(3) Operation.

The preferred rate of build-up is based upon the size of the initial technical staff and what has been judged to be an effective training period for staff additions. Figure 13 illustrates the types and numbers of personnel needed to man the ECIC if it were built up at the rate shown in Figure 12.

Figure 12 shows the estimated rate at which component groups could be added most efficiently for an ECIC. The rate shown is based upon a nucleus of six engineers. The size of the group would approximately double every six months until the total necessary technical staff would have been procured and trained — a period of about thirty months, during which about fifty-four engineers would have become available. The necessary supervisory staff, technical assistance, and clerical help are also shown.

The number of people in each category estimated to be needed are tabulated in Table 3. The last three columns of the table show the daily, monthly, and yearly costs for wages and salaries. Figures are based on pay rates as listed in Table 1.

The total estimated cost requirements to build up and operate an ECIC are shown in Figure 14 and tabulated in Table 4. These estimates were obtained by summing the total costs per component group, as shown in Figure 11, according to the rate of build-up shown in Figure 12. The estimates indicate a total initial cost rate of \$11,600 per month while two component groups are being inserted into the ECIC files. After data on 35 components had been inserted and made ready for question-answering service, the costs would be about \$128,300 per month. This would give an annual operation cost of about \$1,540,000.

TABLE 3. ESTIMATED PERSONNEL REQUIREMENTS AND COSTS FOR ECIC BUILD-UP AND OPERATION

Time After Start of Activation, 6-month periods	Number of Component Groups: First 6-Month Period After Start	Second 6-Month Period After Start	Full-Scale Operation	Number of Personnel Required: Super.	Engrs.	Asst.	Steno Clerical	Total	Costs for Personnel Only, dollars: Per Day*	Per Month	Per Year**
First	2	0	0	1-1/5	6	4	-2/5	11-3/5	355	7,100	--
Second	2	2	0	2-2/5	12	8	4-4/5	23-1/5	710	14,200	127,800
Third	4	2	2	4-1/5	21	16	8-2/5	49-3/5	1,277	25,550	--
Fourth	4	4	4	6	30	24	12	72	1,845	36,900	385,000
Fifth	8	4	8	9-3/5	48	40	19-1/5	118-4/5	2,980	59,600	--
Sixth	4	8	12	10-4/5	54	48	21-3/5	134-2/5	3,405	68,100	826,000
Seventh	4	4	20	10-4/5	54	56	21-3/5	142-2/5	3,545	70,900	--
Eighth	4	4	24	10-4/5	54	64	24	152-4/5	3,970	79,400	903,000
Ninth	3	4	28	10-4/5	54	70	25-1/5	160	4,217	84,350	--
Tenth	0	3	32	10-4/5	54	70	22-4/5	157-3/5	3,932	78,650	979,000
After 5 years	0	0	35	10-4/5	54	70	21	155-4/5	3,718	74,375	893,000

*Monthly cost divided by 20.

**Monthly cost of first and second, third and fourth, fifth and sixth etc., 6-month periods added together and multiplied by six.

TABLE 4 SUMMARY OF ESTIMATED COSTS FOR ECIC BUILD-UP AND OPERATION

6-Month Periods After Start	Number of Component Groups: First 6-Month Period After Start	Second 6-Month Period After Start	Full-Scale Operation	Personnel, $/month	Overhead, 45% of Personnel	Misc., $/month	Travel, $/month	Machines, $/month	Total, $/month	Total, $/year
First	2	0	0	7,[illegible]00	3,200	300	450	540	11,590	--
Second	2	2	0	14,200	6,400	600	900	1,080	23,180	208,620
Third	4	2	2	22,550	11,450	1,100	1,550	2,393	42,043	--
Fourth	4	4	4	36,900	16,600	1,500	2,200	3,710	60,910	617,718
Fifth	8	4	8	59,600	26,800	2,600	3,580	6,690	99,270	--
Sixth	4	8	12	68,100	30,650	3,000	3,900	8,240	113,890	1,278,960
Seventh	4	4	20	70,900	31,900	3,200	3,800	9,390	119,690	--
Eighth	4	4	24	79,400	35,700	3,600	4,200	11,440	134,540	1,524,[illegible]00
Ninth	3	4	28	84,350	37,300	3,850	3,975	12,700	142,775	--
Tenth	0	0	32	78,650	35,400	3,650	3,875	13,160	134,735	1,665,060
After 5 years	0	0	35	74,375	33,400	3,500	3,500	13,000	128,275	1,539,300

Operations Analysis of Operating Costs

A different approach to the operating costs of an ECIC is given by an operations analysis. The analysis provided here is based on certain assumptions regarding the amount of business an ECIC would handle. Since the costs would vary as different sets of assumed values are used, the analysis is worked out in detail for two different rates of activity. However, each element of the operation is costed, so it is possible to calculate the operating costs for any reasonable set of assumed operating figures.

Figure 15 shows the various operations or tasks that are needed to keep an ECIC operating. Two separate main lines of operation are shown. One, headed "New Data", represents the work involved in putting new data into the file; the other, headed "Inquiries", represents the work of answering inquiries.

For the New Data line of operations, it was assumed that:

(1) Four hundred new-data messages are received per day.
(2) The average message covers the characteristics for two components.
(3) The average component has 50 characteristic values supplied.

These assumptions are not dependent upon the rate at which questions are answered, so these values were kept the same when the inquiry rate was varied.

For the Inquiries line of operations, it was assumed that:

(1) Six hundred inquiry messages or 100 inquiry messages are received per day (two rates).
(2) Each inquiry message has <u>five</u> specific questions.
(3) Each question has five characteristic values given.
(4) Each question requires that three characteristic values be established.

The analysis which follows, therefore, is based on two rates of operation, one in which 600 messages per day are answered, and one in which 100 messages per day are answered. For both rates, the maximum time required for a reply to an inquiry is assumed to be 8 working hours after its receipt. Overhead has been assumed to equal the direct labor costs. Note that the overhead rate in the analysis differs from the 45 per cent rate used for the cost estimates at the preceding section. The higher rates used here are to take care of supervisory staff and certain machine costs not included as part of the operations listed.

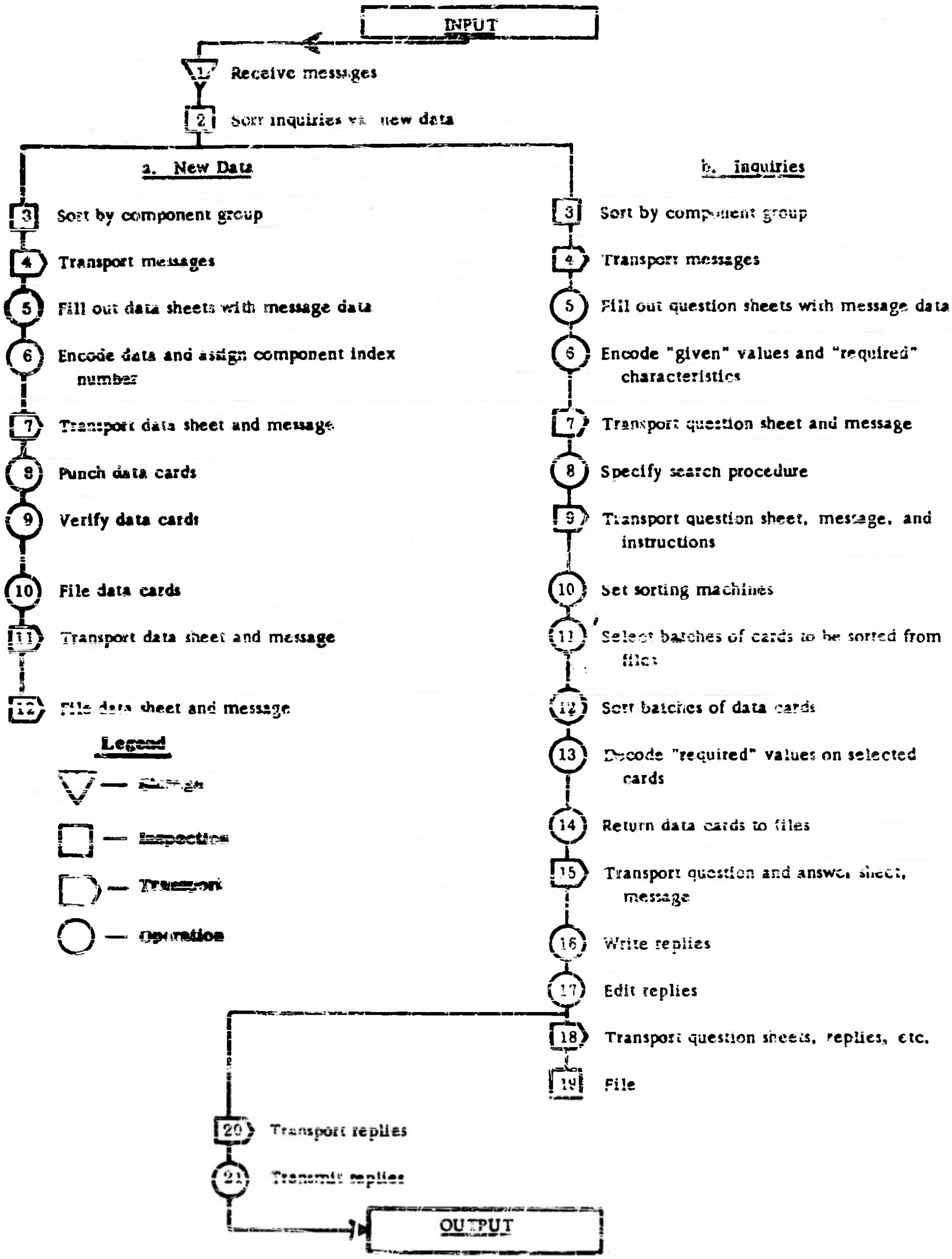

FIGURE 15. OPERATIONAL TASKS OF AN ECIC

TABLE 5. OPERATIONAL TASK SUMMARY FOR AN ECIC

Task	Operations	Operator	Job Description	Pay Rate, dollars/day	Work Rate, units/day
(1) Receiving messages	1, 2, 3a, 3b	Receiving Clerk	Receives messages and sorts them as to whether "new data" or "inquiries" and according to component group.	10	100 messages
(2) Preparing data sheets	5a, 6a	Data Analyst	Lists message data on data sheets and encodes and converts them to system form. Initiates requests for more complete information.	16	80 data sheets
(3) Punching data cards	8a	Punch Operator	Operates alphabetical printing punch IBM No. 026.	11	500 data cards
(4) Verifying data cards	9a	Verifier Operator	Operates verifier IBM No. 056.	11	500 data cards
(5) Filing data sheets, etc.	10a, 12a	Filing Clerk	Files all written matter referring to new data.	8	1000 documents
(6) Preparing question sheets	5b, 6b	Data Analyst	Lists "given" characteristic values from inquiries and states "required" characteristics on question sheets. Rejects inquiries lacking sufficient "given" information.	16	120 question sheets
(7) Specifying search procedures	8b	Search Specialist	Prepares instructions for finding required data from IBM data cards and prepares standard plug boards	20	50 inquiries

TABLE 5. (Continued)

Task	Operations	Operator	Job Description	Pay Rate, dollars/day	Work Rate, units/day
(8) Searching	10b to 14b, inclusive	Machine Operator	Follows search instructions to select and decode required information with IBM machines.	12	120 1000-card batches
(9) Writing replies	15b	Reply Writer	Composes replies to inquiries from selected data. Makes simple calculations.	11	50 replies
(10) Editing replies	16b	Reply Editor	Checks replies for completeness and accuracy, and supervises "content" functions of inquiry processing.	25	100 replies
(11) Transmitting replies	19	Transmitting Clerk	Transmits reply to inquirer by letter, telephone, telegraph, or teletype, as instructed.	11	50 replies
(12) Filing question sheets, etc.	18	Filing Clerk	Files all written matter referring to inquiries.	8	1000 documents
(13) Transporting	All	Messenger	Transports paper between operators as required.	8	--

TABLE 6. ANALYSIS OF DAILY OPERATIONS

Inquiry Rate = 600 Messages Per Day

Task	Work Requirements	Operators: Work Rate	Operators: Required Number	Operators: Pay Rate, dollars	Operators: Cost, dollars	Machines: Number Required	Machines: Cost Rate, dollars	Machines: Cost, dollars	Total Cost, dollars
(1) Receiving messages	1000[a] messages	100	10 Receiving Clerks	10	100	None	--	--	100
(2) Preparing data sheets	800[a, b] data sheets	80	10 Data Analysts	16	160	None	--	--	160
(3) Punching data cards	2400[d] cards	500	5 Punch Operators	11	55	5	2.80	14	69
(4) Verifying data cards	2400 cards	500	5 Verifier Operators	11	55	5	2.80	14	69
(5) Filing data sheets, etc.	800 data sheets 400 messages	1000	1-1/2 Filing Clerks	8	12	None	--	--	12
	2400 cards	(Filed by Punch and Verifier Operators)			--	None	--	--	--
(6) Preparing question sheets	3000[a, c] question sheets	120	25 Data Analysts	16	400	None	--	--	400
(7) Specifying search procedures	600 inquiries	50	12 Search Specialists	20	240	None	--	--	240

Footnotes appear on page 140.

TABLE 6. (Continued)

Task	Work Requirements	Operators: Work Rate	Operators: Required Number	Operators: Pay Rate, dollars	Operators: Cost, dollars	Machine: Number Required	Machine: Cost Rate, dollars	Machine: Cost, dollars	Total Cost, dollars
(8) Searching IBM Punch Cards	6000[e] 1000-card batches	120	50 Machine Operators	12	600	50	11.20	560	1160
(9) Writing replies	600[f] replies	50	12 Reply Writers	11	132	None	--	--	132
(10) Editing replies	600 replies	100	6 Reply Editors	25	150	None	--	--	150
(11) Transmitting replies	600 replies	50	12 Transmitting Clerks	11	132	None	--	--	132
(12) Filing question sheets and replies	3000 question sheets 600 replies	1000	1/2 File Clerks	8	28	None	--	--	28
(13) Transporting	As required	--	3 Messengers	8	24	None	--	--	24
			155 Operators		$2088 per day, operations			$589 per day, machines	$2826 per day, direct costs

Footnotes appear on page 140.

Footnotes For Table 6.

(a) Assuming 400 new-data messages plus 600 inquiry messages, or 1000 messages per day, total.
(b) Assuming 2 components per new-data message times 1 data sheet per component, or 2 data sheets per new-data message.
(c) Assuming 5 questions per inquiry message times 1 question sheet per question, or 5 question sheets per inquiry message.
(d) Assuming 3 cards per data sheet.
(e) Assuming 2 1000-card batches per question sheet.
(f) Assuming 1 reply per inquiry.

TABLE 7. ANALYSIS OF DAILY OPERATIONS

Inquiry Rate = 100 Messages Per Day

Task	Work Requirements	Operators: Work Rate	Operators: Required Number	Operators: Pay Rate, dollars	Cost, dollars	Machines: Number Required	Machines: Cost Rate, dollars	Machines: Cost, dollars	Total Cost, dollars
(1) Receiving messages	500[a] messages	100	5 Receiving Clerks	10	50	None	--	--	50
(2) Preparing data sheets	800[a, b] data sheets	80	10 Data Analysts	16	160	None	--	--	160
(3) Punching data cards	2400[d] cards	500	5 Punch Operators	11	55	5	2.80	14	69
(4) Verifying data cards	2400 cards	500	5 Verifier Operators	11	55	5	2.80	14	69
(5) Filing data sheets, etc.	800 data sheets 400 messages	1000	1-1/2 Filing Clerks	8	12	None	--	--	12
	2400 cards		(Filed by Punch and Verifier Operators)						
(6) Preparing question sheets	500[a, c] question sheets	120	4-1/6 Data Analysts	16	67	None	--	--	67
(7) Specifying search procedures	100 inquiries	50	2 Search Specialists	20	40	None	--	--	40

Footnotes appear on page 143.

TABLE 7. (Continued)

Task	Work Requirements	Operators: Work Rate	Operators: Required Number	Operators: Pay Rate, dollars	Operators: Cost, dollars	Machines: Number Required	Machines: Cost Rate, dollars	Machines: Cost, dollars	Total Cost, dollars
(8) Searching IBM punch cards	1000[e] 1000-card batches	120	8-1/3 Machine Operators	12	100	8-1/3	11.20	94	194
(9) Writing replies	100[f] replies	50	2 Reply Writers	11	22	None	--	--	22
(10) Editing replies	100 replies	100	1 Reply Editor	25	25	None	--	--	25
(11) Transmitting replies	100 replies	50	2 Transmitting Clerks	11	22	None	--	--	22
(12) Filing question sheets and replies	500 question sheets 100 replies	1000	1/2 File Clerks	8	4	None	--	--	4
(13) Transporting	As required	--	1 Messenger	8	8	None	--	--	8
			52-1/2 Operators		$620 per day, operations			$122 per day, machines	$742 per day, direct costs

Footnotes appear on page 143.

Footnotes for Table 7

(a) Assuming 400 new-data messages plus 100 inquiry messages, or 500 messages per day, total.

(b) Assuming 2 components per new-data message times 1 data sheet per component, or 2 data sheets per new-data message.

(c) Assuming 5 questions per inquiry message times 1 question sheet per question, or 5 question sheets per inquiry message.

(d) Assuming 3 cards per data sheet.

(e) Assuming 2 1000-card batches per question sheet.

(f) Assuming 1 reply per inquiry.

The information-handling techniques of an ECIC have been reduced to the operations shown in Figure 15, which lists the details of the system operation. Each sequence of operations performed in a cycle at each work station is a "task" — the basic definition of the job of each operation. Table 5 shows, for each "task", the kind of operator employed, and a short description of his job. His assumed pay rate and work rate are also indicated.

The costs of performing each task for the 600-inquiry-messages-per-day and the 100-inquiry-messages-per-day rates of operation* are shown in Tables 6 and 7, respectively. The second column of each table contains a statement of the work requirements based on the assumed work loads. The number of operators needed for a task is obtained by dividing the daily work requirements by the daily work rate. The operator cost per day for a task is the number of operators times the daily pay rate. That is:

$$\frac{\text{Daily work requirements}}{\text{Daily work rate per operator}} = \text{number of operators (for a task).}$$

Number of operators x daily pay rate = daily operator cost (for a task).

One machine per operator was assumed for the tasks requiring machines.

Table 8 shows the basis upon which machine costs were estimated. These estimates are believed to be on the high side, since it should be possible to substitute less expensive sorters and collating machines for some of the electronic statistical machines. However, these savings depend upon the operating efficiencies of a large, well-integrated installation, and cannot be predicted accurately in advance.

TABLE 8. ESTIMATES OF DAILY MACHINE RENTALS

Task Number	Task	Operation	Machine	IBM No.	Cost Rate, dollars/day
(3)	Punching data cards	8a	Printing-card punch	026	2.80
(4)	Verifying data cards	9a	Card verifier	056	2.80
(8)	Searching	12b	Electronic statistical machine	101	11.20

*These rates are equivalent to 3000 questions per day and 600 questions per day, respectively, as the average message has been assumed to contain 5 specific questions.

The direct daily operating costs for each "task", for each rate of operation, are listed in the last columns of Tables 6 and 7. The figures are summarized in Table 9, and the costs for various elements of the operation are shown in Table 10.

Evaluation of Cost Elements

From Table 9, we see that an average question can be answered for $1.59 or $2.72, depending upon the rate at which the ECIC is used. These figures represent the ECIC internal operating cost of a search through all the available data. They appear to be less than the costs of data searching by present-day methods by one or two orders of magnitude.

A major difficulty encountered by an engineer today is the problem of assembling all of the available data. Even after he has gathered the information into one location, a search through the data is a tedious task unless the data are organized systematically. If the data are organized properly, a manual search is normally not excessive in cost, but probably the cost still would be two or three times the ECIC projected amounts (Table 9). Since the ECIC system was conceived (1) to locate centrally as much as possible of the available data, (2) to organize the data for efficiency in searching, and (3) to utilize the most effective means of searching the store of data to answer inquiries, it should do much to alleviate this difficulty.

Table 10 shows the extent to which the various functions of the ECIC affect the over-all cost. From A, B, and C of Table 10, it is evident that the number of inquiries answered per day is an important factor in the cost per inquiry. Variations in cost are shown to be due almost entirely to the costs of putting data into the system. The table also shows that, unless a system such as the ECIC is to be used extensively, it cannot be justified on the grounds of economy alone. On the other hand, sufficient use of a system like the ECIC could reduce the costs of finding available data, so that these costs no longer would be a major item in the development costs of electronic equipment.

The costs of searching a file for an answer to an inquiry do not necessarily represent a major part of the system costs (A, B, C, and D of Table 10). This point is frequently overlooked when various systems are compared. The costs of putting data into the system, analyzing questions, analyzing and editing answers, and preparing replies are other cost factors, some of which could exceed the actual costs of searching. Since, in making his own search, an engineer would do his own analyzing and editing in the course of his search, consideration must be given to the fact that a system such as the ECIC introduces new cost elements to the problem of searching for information.

TABLE 9. ESTIMATED COSTS PER MESSAGE AND PER QUESTION

	Rates of Operation	
	600 Inquiry Messages/Day	100 Inquiry Messages/Day
Direct Operator Costs, dollars/day	$ 2,088 (155 operators = 53 tech. + 102 nontech.)	$ 620 (52 operators = 17 tech. + 35 nontech.)
Machine Costs, dollars/day	588	122
Total Direct Costs, dollars/day	2,676	742
Overhead, 100% of Operator Costs, dollars/day	2,088	620
Total Costs, dollars/day	$ 4,764	$ 1,362
Average Cost per Inquiry Message	7.94	13.62
Average Costs per Question Answered	1.59	2.72
Total Estimated Costs per Month	$ 100,000	$ 28,550
Total Estimated Costs per Year	$1,200,000	$342,500

TABLE 10. ANALYSIS OF COST ELEMENTS

	600 Inquiry Messages Per Day		100 Inquiry Messages Per Day	
	Cost of Operation, dollars/day	Cost of Operation, percentages	Cost of Operation, dollars/day	Cost of Operation, percentages
A. Total direct costs per day, Tasks 1 through 13	2676		742	
B. Direct costs of putting data into system, Tasks 1 through 5	350	13. 1% of A	350	47. 2% of A
C. Direct costs of answering inquiries, Tasks 1 through 13	2326	86. 9% of A	392	52. 8% of A
D. Cost of searching, Task 8	1160	43. 4% of A 49. 6% of C	194	25. 2% of A 49. 6% of C
E. Machine charges for searching, Task 8, machine charges only	560	20. 9% of A 24. 0% of C 43. 4% of D	94	12. 7% of A 24. 0% of C 48. 4% of D
F. Machine charges for putting data into system, Tasks 3 and 4, machine charges only	28	1. 0% of A 8. 0% of B	28	3. 8% of A 8. 0% of B

When machines are used for data-insertion and searching operations, both their effectiveness and their costs must be considered. Items E and F of Table 10 show how widely machine costs can vary. These figures are not evidence for or against machines, but merely show the sensitivity of certain operations to machine charges. Cost figures used as justification for machines would require a complete operational analysis for alternative systems.

However, the data of Table 10 do indicate the places where effort for improvement may be directed more profitably. As an example, the machine costs for putting data into the system (Item F, Table 10) are only 1 per cent of the total system costs and but 8 per cent of the costs of putting data into the system. On the other hand, the machine costs for searching (Item E, Table 10) are 20.9 per cent of the total system costs, 24.0 per cent of the over-all cost of answering a question, and 48.4 per cent of the actual searching costs. The conclusion to be drawn from these figures is that improvements in searching machines offer the promise of worth-while additional savings in searching costs. It should also be noted, however, that, if the number of searches is low, the savings due to improved machines would not offset the costs of effecting the savings.

Conclusions on Cost Analysis

The conclusions that can be drawn from the cost information presented here are that:

(1) The initial costs of processing input data, per unit of data, will be higher than the ultimate steady-state operating costs of obtaining data.

(2) The minimum time required to put the ECIC into operation is six to twelve months. Four to five years is recommended as the time to allow for putting the ECIC into operation if maximum efficiency is desired.

(3) The cost estimates indicate that the cost of service for a rate of 100 inquiries per day (each inquiry having five questions) would be \$13.62 per inquiry, or \$2.72 per question. The estimates indicate that, for a rate of 600 inquiries per day (each inquiry having five questions), the cost would be \$7.94 per inquiry, or \$1.59 per question.

(4) More accurate estimates of operating costs could be made only after a period of pilot-plant operation. The above estimates, however, should provide valuable information for planning purposes.

PART V

CONCLUSIONS

(1) A design has been completed for a punched-card system for insertion, storage, retrieval, and dissemination of technical data on the procurement and performance characteristics of fifteen basic groups of electronic components, as follows:

Resistors
Capacitors
Motors
Dynamotors
Relays (including circuit breakers)
Switches
Piezoelectric crystals
Vibrators
Inductors (coils)
Batteries
Dry-disk rectifiers
Indicating instruments
Fuses
Connectors (plugs, sockets, and jacks)
Lamps

This design provides detailed procedures for the establishment of an Electronic Component Information Center to serve industry and the Armed Forces. It might provide, at high speed, the technical information that is available on electronic components, to expedite the design, development, production, and maintenance of electronic equipment.

(2) Methods have been developed for recording nearly all forms of technical data (words, numbers, curves, families of curves, statistical data, formulas, and relationships) in concise form on business-machine punched cards, in forms suitable for automatic searching and reproduction of selected data. These methods are designed for use on presently available punched-card machines. Exploratory tests, using conventional machines, indicate that the methods are workable.

(3) A series of data sheets, codes, and definitions has been developed for the important characteristics of fifteen groups of electronic components (see list in Conclusion 1 above). These are consistent with existing military specifications and test procedures where applicable. It was recognized that standardized specifications and test procedures are not adequate to appraise the performance of electronic components under abnormal service conditions. It was further recognized that performance data under abnormal

conditions would be helpful to designers engaged in developing new systems extending to more extreme performance levels. Accordingly, a portion of the project was devoted to designing and evaluating appropriate test procedures. In particular, tests designed to measure the performance and life characteristics of some electronic components under abnormal temperatures were studied experimentally.

Although the filing system was designed to have the capacity for accepting performance data of every type, it was recognized that the reliability and usefulness of data extending beyond recognized standards will depend on close cooperation between the manufacturers and the agencies or laboratories obtaining the data. The cooperation will involve agreement not only on sampling methods, but also on the degree to which test procedures provide the desired information.

(Details as to how this cooperation could be worked out were not a part of this investigation.)

APPENDIX I

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(2) Many helpful suggestions or assistance were provided by members of the technical staffs of the following organizations:

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APPENDIX B

PROJECT REPORT LIST AND LABORATORY RECORDS

Project Reports

(1) First Interim Engineering Report, February 28, 1949, 14 pages, R. L. Davis, C. F. Rains, and R. C. McMaster.

(2) Second Interim Engineering Report, April 28, 1949, 13 pages, R. L. Davis, R. L. Merrill, C. F. Rains, R. W. Whitmore, and R. C. McMaster.

(3) Third Interim Engineering Report, June 28, 1949, 21 pages, R. L. Davis, R. L. Merrill, C. F. Rains, R. W. Whitmore, and R. C. McMaster.

(4) Fourth Interim Engineering Report, August 28, 1949, 19 pages, R. L. Davis, R. L. Merrill, C. F. Rains, R. W. Whitmore, and R. C. McMaster.

(5) Fifth Interim Engineering Report, October 28, 1949, 29 pages, R. L. Davis, R. L. Merrill, C. F. Rains, and R. C. McMaster.

(6) Sixth Interim Engineering Report, December 28, 1949, 22 pages, R. L. Davis, A. T. Maierson, R. W. Whitmore, R. L. Merrill, C. F. Rains, and R. C. McMaster.

(7) Seventh Interim Engineering Report, February 28, 1950, 36 pages, R. L. Davis, A. T. Maierson, R. L. Thompson, R. L. Merrill, C. F. Rains, and R. C. McMaster.

(8) Eighth Interim Engineering Report, April 28, 1950, 34 pages, R. L. Davis, A. T. Maierson, R. K. Crooks, R. E. Keppler, E. Zoltanski, R. L. Merrill, C. F. Rains, and R. C. McMaster.

(9) Ninth Interim Engineering Report, June 28, 1950, 30 pages, R. L. Davis, A. T. Maierson, R. K. Crooks, R. E. Keppler, E. Zoltanski, R. L. Merrill, C. F. Rains, and R. C. McMaster.

(10) Tenth Interim Engineering Report, August 28, 1950, 36 pages, R. L. Davis, A. T. Maierson, R. K. Crooks, W. E. Carpenter, R. E. Keppler, R. E. Martin, H. Sura, R. L. Merrill, C. F. Rains, and R. C. McMaster.

(11) Eleventh Interim Engineering Report, October 29, 1950, 24 pages, R. L. Davis, A. T. Maierson, W. E. Carpenter, R. E. Keppler, R. E. Martin, H. Sura, R. L. Merrill, C. F. Rains, and R. C. McMaster.

(12) Twelfth Interim Engineering Report, December 28, 1950, 22 pages, R. L. Davis, A. T. Maierson, R. E. Martin, R. L. Merrill, and R. C. McMaster.

(13) Thirteenth Interim Engineering Report, September 30, 1951, "A Study of the Prediction of Composition-Resistor Life", 76 pages, D. B. J. Bridges, W. T. Sackett, Jr., and J. H. Graham.

(14) Supplement to the Thirteenth Interim Engineering Report, February 29, 1952, "A Study of the Prediction of Predried Composition-Resistor Life", 26 pages, D. B. J. Bridges, W. T. Sackett, Jr., and J. H. Graham.

(15) Fourteenth Interim Engineering Report, October 30, 1952, "A Study of the Behavior of Capacitor Characteristics at Elevated Temperatures", 37 pages, F. E. Berger and G. M. L. Sommerman.

(16) Tentative Data Sheet Manual for Electronic Component Information Center, June 28, 1952 (revisions of these data sheets are now contained in the series of Special Reports below), 120 pages, R. L. Davis, A. T. Maierson, R. E. Keppler, R. E. Martin, R. K. Crooks, W. E. Carpenter, H. Sura, R. L. Merrill, and R. C. McMaster.

(17) Tentative Code Book for ECIC, June, 1951 (revised March, 1954), 130 pages, R. L. Davis, A. T. Maierson, R. E. Keppler, R. E. Martin, R. K. Crooks, W. E. Carpenter, H. Sura, R. L. Merrill, and R. C. McMaster.

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